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M.A., Ph.D., F.R.G.S., F.C.S., F.E.I.S.,
Author of "Animal Physiology," "Inorganic Chemistry," &c., and Joint Editor of the "Extra Subject Series" of Educational Works.

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PREFACE.

The rapid sale of large impressions of this work is a satisfactory proof of the estimation in which it is held by science teachers, heads of schools, and the public. In it will be found answers to most of the questions proposed in both the elementary and advanced stages at the Science Examinations during the last six years. As too much stress cannot be laid on the necessity of practice in paper work, teachers are strongly recommended to see that their pupils work the "Home Exercises" found at the end of the book, according to the instructions given. Students requiring more advanced text-books will do well to provide themselves with Huxley's "Lessons in Elementary Physiology," and Buckmaster's "Animal Physiology," two works that have been found valuable in the preparation of the present volume.

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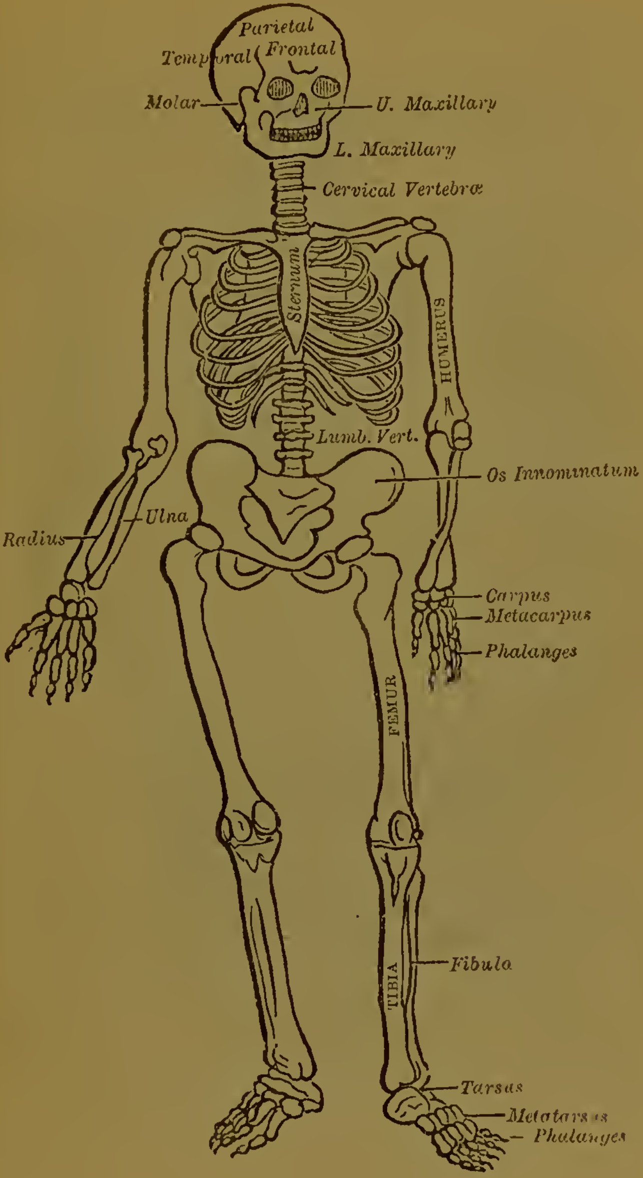
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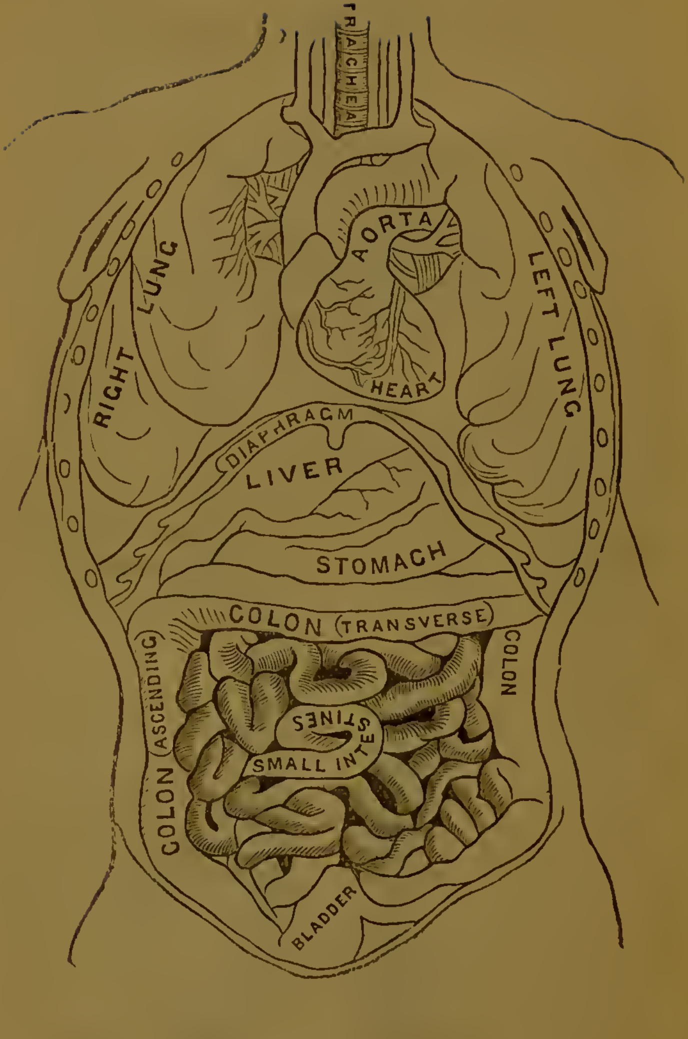
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ANIMAL PHYSIOLOGY,

FOR

ELEMENTARY CLASSES.

DEFINITIONS.

ABBREVIATIONS USED.—Sc. Ex., Science and Art Department Examination. E., Elementary Stage. A., Advanced Stage. The numbers at the end of the questions refer to the numbers of the paragraphs where the answers may be found.

1. **The Skull** (Danish, *skall*, a shell, the skull), or **Cranium** (Greek, *kranion*), is the shell of bone that forms the exterior of the head and incloses the brain. It consists of eight bones; namely, one *frontal* bone, forming the forehead; one *occipital* bone at the back part of the head; two *parietal* bones, covering the top, sides, and back of the head; two *temporal* bones, forming the temples; one *ethmoid* and one *sphenoid* concerned in the formation of the nose and orbits.

2. **The Vertebræ** (Latin, *vertebra*, from *verto*, to turn) are the bones of the spine, or *dorsal column* of an animal.

There are two kinds of vertebræ which compose the spine, namely, the *true* and *false*. The true vertebræ are further divided into *cervical*, *dorsal*, and *lumbar*; or those of the neck, back, and loins. The vertebræ are united together by a compressible substance (cartilage), which forms a bond of union between them, and admits of a certain degree of motion between the bodies of the vertebræ, small between individual bones, but considerable as respects the whole spinal column. The vertebræ and their projections, or processes, also afford attachments for a number of muscles and ligaments; passages are also excavated in them for blood vessels, and for the nerves that pass out of the spinal cord.

3. **The Ribs** (Saxon, *rib* or *ribb*) are the bones which form the top and sides of the framework of the thorax. In the human body there are twelve ribs on each side, proceeding from the spine towards the sternum, and serving to inclose and protect the heart and lungs. The seven upper ribs are called *true ribs*, and the five lower ones, *false ribs*. The true ribs are connected with the sternum by cartilages.

4. **The Thorax** (Latin, *thorax*, the breast) is a closed cavity bounded by the ribs, along the sides and at the top, and by the diaphragm beneath. It contains the pleura, lungs, heart, œsophagus, thoracic duct, &c.

5. **The Sternum** (Greek, *sternon*), or breast bone, forms the front of the human chest from the neck to the diaphragm. It is flat and narrow, and consists of three pieces.

6. **The Scapula**, plural scapulæ (Latin), is the shoulder blade. There are two of these irregular shaped bones in the body, by which the arms are attached to the trunk.

7. **The Clavicle** (Latin, *clavicula*, a tendril; that is, a little key or fastener, from *clavis*, a key), or collar bone, is a long, double curved bone, resembling the letter *ƒ* in shape. There are two clavicles, joined at one end to the scapula or shoulder bone, and at the other to the sternum or breast bone. Their use is to keep the upper limbs from the body so as to allow of very free motion.

8. **The Humerus** (Latin), or bone of the upper arm, has a rounded head, which is inserted into the glenoid cavity; a neck, a shaft, and a lower extremity, having two expansions or condyles, and also two

---

Sc. Ex., 1868, E.—What are the ribs? How many does a man possess, and what cavity do they help to enclose? 3 and 182.

cavities or depressions corresponding to the heads of the bones of the fore arm, which forms a hinge joint with it.

9. **The Fore Arm,** or lower arm, consists of two bones—the *ulna* and the *radius.*

10. **The Ulna** (Greek, *olene,* the elbow) is the shorter of the two bones of the fore arm, reaching from the elbow to the wrist. Its upper extremity forms the point of the elbow. Its chief use appears to be to support and regulate the motions of the radius, the other bone of the fore arm.

11. **The Radius** (Latin) is the exterior bone of the fore arm when the palm is turned upward, descending along with the ulna from the elbow to the wrist.

12. **The Hand** consists of three parts—the carpus, or wrist; the metacarpus, or palm; and the phalanges, or fingers.

13. **The Carpus** (Greek, *carpos,* the wrist), or wrist, comprises eight small bones united by ligaments, and arranged in two rows.

14. **The Metacarpus** (Greek, *metacarpion,* from *meta,* beyond, and *carpos,* the wrist) is the part of the hand between the wrist and the fingers. The metacarpal bones consist of five long prismoidal bones, attached to the lower row of the carpal bones.

15. **The Phalanges** (Greek, *phalanx*) are the rows of small bones forming the fingers, or the toes, distinguished into the first, second, and third phalanges.

Those of the fingers consist of fourteen small long bones, arranged in three rows, the upper row being attached to the lower metacarpal bones. Each finger has three phalangos; the thumbs only two.

16. **The Pelvis** (Latin, *pelvis,* a basin) is the lowest cavity of the trunk formed by four immovable bones, namely, the two *ossa innominata,* or nameless bones,

the *os sacrum*, and the *os coccyx*. Each *os innominatum* is subdivided into the *ilium*, *ischium*, and *pubis*.

17. **The Bones of the Lower Extremities** comprise two femurs, or thigh bones; two patellæ, or knee-pans; two tibia, or shin-bones; two fibulæ, or splint-bones; seven tarsi, or ankle-bones, in each foot; five metatarsi, or instep-bones; and the fourteen phalanges of the toes.

18. **The Femur** (Latin, *femur*, the thigh), os femoris, or thigh bone, is the largest and strongest bone in the body. It corresponds in structure to the humerus in the arms. It has a head, neck, shaft, and lower extremity, with two condyles. The upper end of the shaft has two large bony protuberances called the greater and less trochanters.

19. **The Patella** (Latin), or knee-pan, is a flat bone, triangular in shape, which is situated in front of and protects the knee-joint.

20. **The Tibia** (Latin), or shin-bone, is a long, thick, nearly vertical bone, situated at the front and inner side of the leg. Its name is said to have reference to its resemblance to the ancient pipe or flute, called a *tibia*.

21. **The Fibula** (Latin, *fibula*, a buckle), or splint-bone, is the outer and lesser bone of the leg; so named on account of its connecting and giving firmness to the other parts. It is parallel to the *tibia*, to the upper and lower extremities of which it is immovably fixed.

22. **The Foot** supports the body, and is one of the necessaries to locomotion and support. It consists of three parts, the tarsus, or upper instep; the metatarsus, or lower instep: and the phalanges, or toes.

23. **The Tarsi,** singular tarsus (Greek *tarsos*, sole of the foot), of each foot comprise seven irregular-shaped

bones—the os calcis, or heel-bone; astragalus (Greek, *astragalos*, ankle); cuboid; navicular bone; and the internal, middle, and external cuneiform bones.

24. **The Metatarsus** (Greek *meta*, beyond, and *tarsus*) is the middle of the foot, or part between the ankle and the toes. The *metatarsal* bones compose the broad part and front of the arch of each foot, or its lower instep. Each foot has five long bones, corresponding with the toes, and having a shaft and two extremities.

25. **The Integument** (Latin, *integumentum* from *intego*, to cover), or skin, is a tough membrane which invests the whole body.

26. **Mucous Membranes** consist of—1, an exterior layer of compact areolar tissue, continuous with the ordinary subjacent areolar tissue, by which it is attached to the adjacent surfaces; this layer is well supplied with blood vessels, though but sparingly with nerves; 2, a middle layer of structureless basement membrane; 3, an epithelial layer, on its inner or free surface, consisting of a single or multiple layer of epithelial cells. They are moistened by mucus, and possess the ordinary physical qualities of areolar tissue.

27. **Connective Tissue** (also called *fibrous* or *areolar* or sometimes *cellular* tissue) consists of bands or cords, or sheets of a whitish substance, having a fibrous appearance, and capable of being split up into a great number of fine filaments. When boiled it swells up and yields *gelatine*.

28. **A Tendon** (Latin, *tendo*, to stretch) is a hard, insensible cord or bundle of fibres, by which a muscle

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Sc. Ex., 1868, E.—What is the difference between tendon, ligament, and cartilage? 28, 29, 30, 231, and 232.

Sc. Ex., 1871, E.—What are tendons? Of what use are they? 28, 231, and 232.

is attached to a bone or other part which it serves to move. Tendons are white and shining tissues, composed of bundles of delicate fibres, united by cellular tissue. Tendons mostly form the *origins* and *insertions* to the muscles.

29. **A Ligament** (Latin, *ligamentum*, from *ligo*, to bind) is a strong, compact substance, serving to bind one bone to another. It is a white, solid, inelastic, tendinous substance, softer than cartilage, but harder than membrane.

30. **Cartilage** (Latin). A smooth, solid, elastic substance, softer than bone, of a pearly colour and homogeneous texture, with nucleated cells. It is ordinarily known as *gristle.*

31. **Muscles** (French, from Latin *musculus*) are the organs of motion, consisting of fibres or bundles of fibres inclosed in a thin cellular membrane.

The muscles are susceptible of contraction and relaxation, and in a healthy state some muscles are subject to the will, and are called *voluntary* muscles. But others, as those of the heart, the urinary bladder, the stomach, &c., are not subject to the will, and are therefore called *involuntary* muscles. Yet this division into voluntary and involuntary is a bad one, since the involuntary are subject to the will (thus breathing, which is ordinarily involuntarily performed, when modified by the will, gives rise to speech, song, cry, &c.); while, conversely, the voluntary muscles act without the stimulus of the will in the secondary automatic actions, as in the case of the old soldier dropping his pie-dish at the wag's cry of "Attention!"

Sc. Ex., 1867, E.—What is a muscle, and what are the most important properties of muscle? 31, 184, and 190.

Sc. Ex., 1870, E.—Describe the minute structure of muscle. 31, 184, and 190.

The red colour of the muscles is owing to the blood-vessels which they contain. The ends of the muscles are fastened to the bones which they move either directly or by tendons, and when they act in opposition to each other they are called *antagonist.*

32. **A Nerve** (Latin *nervus*, a nerve) is an organ of sensation and regulator of motion in animals. The nerves are prolongations of the medullary substance of the ganglia of the brain, spinal cord, and sympathetic system, which ramify and extend to every part of the body except the extravascular (hair, nails, teeth, &c.). They are composed (1) of bundles of white, parallel, medullary threads; and (2) of nerve cells or corpuscles, which act as centres and junctions. The nerve trunks merely distribute the orders propagated from the brain, or carry in to their centres impressions from without, whereas the grey cells originate the messages transmitted.

We have *afferent* or in-carrying nerves, and *efferent* or out-going nerves, the former for sensation, the latter for motion (voluntary or involuntary).

Every bundle is surrounded with a soft sheath full of blood-vessels, and whose finest branches terminate in the substance of the nerves.

33. **Cilia** (Latin *cilium*, an eyelash) are exceedingly minute, hair-like, vibratory filaments, which form fringe-like processes, attached to the epithelium cells, lining the surface of the larynx, the smaller bronchial tubes, the lower part of the nasal cavities, frontal sinuses (in the skull), lachrymal ducts, Eustachian tubes, velum palati, fauces, &c.

34. **Muscular Tissue** comprises two varieties—striated (striped) and non-striated muscular fibre. The former enters into the structure of the voluntary muscles and the heart, the latter into the structure of the organic or involuntary muscles.

35. **Nervous Tissue** comprises three kinds—white tubular nerve-fibre, as in the cranial and spinal nerves; grey gelatinous nerve-matter interlaced with scattered fibres, as in the sympathetic system; and vesicular nerve-substance, as in the interior of the brain and the ganglia of the cord, and sympathetic.

36. **Corpuscles** (Latin, *corpusculum*, diminutive of *corpus*, a body) are very small flattened round bodies which give colour to the blood, and which convey oxygen to all parts of the body from the lungs, and carbonic acid from the capillaries.

37. **Blood** (Saxon, *blod*). The fluid formed from our food which circulates through the arteries, capillaries, and veins of the body, and which is essential to the functions of life. It consists of blood plasma or liquor sanguinis, red corpuscles or globules, white corpuscles, gases (chiefly oxygen and carbonic acid), extractive matters (urea and uric acid), inorganic substances (salts of soda, potash, magnesia, iron, and salt), besides fibrine, &c.

38. **Lymph** (Latin, *lympha*, water,) is a clear, transparent, colourless, or yellowish fluid, contained in certain vessels called *lymphatics*. It is slightly alkaline, and coagulates spontaneously, in consequence of the presence of fibrine. It may be regarded as the drainage of the waste pipes, used up again when it has been reorganised in the ganglia of the lymphatic system. Probably as much lymph is daily thrown into the circulation of the blood as the whole blood itself amounts to, so that the elaboration of lymph becomes one of the most extensive functions of the body.

39. **Asphyxia** (Greek, *a*, not, and *sphugo*, I beat), or apnœa, is the cessation of breathing. Unless purely temporary it always results in death.

It may be caused by spasm of the glottis or the muscles of respiration, by breathing poisonous or irritating gases, by the withholding of the nervous influence through apoplexy, paralysis, the section of the pneumogastric nerve, the brains becoming charged with venous blood, and obstruction of the mouth or air-passages. It may now be accepted that asphyxia is always ultimately due to oxygen starvation, from whatever cause this may arise. Carbonic acid poisoning is a negative and not a positive condition, as the most recent researches clearly prove.

40. **Sweat** (Saxon *swat*). The sensible moisture which is excreted from the skin of an animal by means of the sudoriparous glands of the dermis.

41. **Bile** (Latin, *bilis*). A greenish alkaline fluid, separated from the blood in the liver. It emulsifies the fatty foods so that they may be absorbed by the lacteal radicles.

42. **A Joint** (French, *joint*) is the joining of two or more bones, as—the elbow, the knee, or the knuckle.

43. **Tympanum** (Latin), the membrane stretched across the passage leading from the outer ear to the middle ear, and more commonly the chamber behind it.

44. **The Brain** (Saxon, *brægan*) is a soft, grey mass, or viscus, inclosed in the cranium or skull, in which the cerebral nerves and spinal marrow terminate, and which is supposed to be the seat of the soul, or intelligent principle in man. It is divided into the two cerebral hemispheres, the cerebellum, the pons varolii uniting the cerebella and the optic ganglia beneath the cerebra. It encloses chambers called ventricles.

45. **The Spinal Cord** is a continuation of the medulla oblongata. It is a flattened cylindrical body, enclosed in the vertebral canal. It reaches from the foramen magnum of the skull to the first lumbar vertebra; is about eighteen inches long, and weighs

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Sc. Ex., 1868, E.—What is a joint? 42. In what way does the hip joint differ from the elbow joint? 230.

Sc. Ex., 1869, E.—What is a joint? 42. Give examples of ball and socket joints, and of hinge joints. 230.

(when its nerves and membranes are detached) about one and a half ounces. It terminates in the cauda equina.

46. **The Pharynx** (Greek, *pharugx*, from *pherein*, to convey) is a muscular bag at the back of the mouth. It is shaped like a funnel, adheres to the fauces behind the larynx, and terminates in the œsophagus. Its use is to receive the masticated food, and convey it to the œsophagus.

47. **The Gullet** (French, *goulet*, from Latin, *gula*), or **Œsophagus** (Greek, *osio*, I shall carry, and *phago*, to eat) is the tube commencing at the lower end of the pharynx, and terminating in the cardiac opening of the stomach. It commences at about the fourth or fifth vertebra, and, after perforating the diaphragm, enters the stomach opposite the tenth dorsal vertebra.

48. **The Stomach** (Latin, *stomachus*) is a curved bag of an irregularly conical form, capable of holding, when full, from three to five pints of food. It lies across the upper part of the abdominal cavity, its larger or cardiac extremity lying on the left side in contact with the lower surface of the diaphragm, and its lesser or pyloric extremity extending a little forward towards the right side underneath the liver as far as the right kidney.

49. **The Intestines** (Latin, *intestinus*, from *intus*, within) are contained in the abdominal cavity, and consist of the tubular portion of the alimentary canal. The whole length of the intestinal tube in man is about five times that of the body. The small intestines, which are connected with the pyloric end of the stomach, are about 20 feet long and 1¼ inches in

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Sc. Ex., 1868, E.—Give an account of the general form of the brain, and the spinal cord, and state how they are protected. 44, 45, and 192.

diameter. They form about five-sixths of the entire length of the intestines. The large intestine is about 5 feet long, and from 2 to 3 inches in diameter. It is a continuation of the small intestines. The intestines are divided into the

(1) **Duodenum**, which commences at the pyloric exit.

(2) **Jejunum**, a continuation of Duodenum.

(3) **Ileum**, or remainder of small intestine.

(4) **The Colon**, Ascending, Transverse, and Descending.

(5) **The Rectum**, or termination of larger intestine.

50. **The Salivary Glands** are conglomerate, racemose (Latin *racemus*, a bunch of grapes), vesicular glands, consisting of numerous lobes made up of lobules, the whole being connected together by ducts, surrounded by bloodvessels, and embedded in areolar tissue.

51. **The Liver** (Saxon *lifer*) is a glandular organ for secretion of a reddish-brown colour. It is the largest gland in the body, is about thirteen inches long and seven inches broad, measures about ninety cubic inches, and weighs from three to five pounds. It is situated in the upper part of the abdomen, immediately under the right half of the diaphragm, into the concavity of which it is fitted, and to which it is attached. It lies above and rests on a portion of the stomach, upper part of the colon, and the kidney.

52. **The Pancreas** (Greek *pan*, all, and *kreas*, flesh), or sweetbread, is a soft, milky gland of the body, situated between the bottom of the stomach and the

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Sc. Ex., 1871, A.—Give an account of the structure of the liver. 51 and 218. State what is known concerning the formation of bile and of glycogen. 222 and 221.

vertebræ of the loins, reaching from the liver to the spleen, and attached to the peritoneum. It is about seven inches long, three inches broad, and from one to two inches thick. It secretes about half a pint per day of a fluid called the pancreatic juice, closely resembling saliva in appearance and function, and which it pours into the duodenum.

53. **The Larynx** (Greek *larugx*, the orifice of the wind-pipe), or organ of the voice, somewhat resembles an irregular inverted cone in shape. It is situated at the top of the trachea or wind-pipe, immediately in front of the œsophagus, and under the root of the tongue.

54. **The Trachea** (Greek *trachus*, rough), or wind-pipe, is a cartilaginous and membranous pipe through which the air passes into and out of the lungs. At its upper extremity is situated the larynx.

55. **The Lungs** (Saxon, *lungen*) are the organs of respiration in man and many other animals. There are two of these organs, each of which occupies a separate cavity in the thorax. They alternately inhale and expel the air, by means of which the necessary function of respiration is carried on. In ultimate analysis the lungs are composed of loose, spongy texture, enclosing minute air cells, surrounded by capillaries, and holding together the bronchi which finally terminate in the trachea. There are three lobes to the right lung and two to the left.

56. **The Kidneys** are two dark, reddish-brown, bent, oval-shaped bodies, situated in the loins, at the back of the abdominal cavity, one on each side of the lowest dorsal and upper lumbar vertebræ. They lie outside and behind the peritoneum, the left kidney

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Sc. Ex., 1867, E.—What is the position of the heart, the lungs, the liver, and the kidneys? 58, 51, 55, 56, and 182.

lying behind the larger end of the stomach. They are about five inches long, two inches wide, and one inch thick, and weigh about five ounces each.

57. **The Bladder** (Saxon, *blœdr*) is a thin, membranous, hollow, conical bag, which receives the urine as it leaves the ureters. When distended, it will hold from nine to twelve pints of liquid. If the bladder should become ruptured, so that any of the urine is able to escape into the adjacent tissues, death usually follows; urea, the principal constituent of the urine, being a powerful blood poison, acting as a narcotic on the brain.

58. **The Heart** (Saxon, *heort*), which is the principal organ of circulation, consists of a hollow, conical, muscular bag. It is situated in the centre of the thorax, between the lungs. The lower end of it beats against the walls of the chest in the space between the fifth and sixth ribs, from two to three inches to the left of the sternum, where its action can be most distinctly felt. The heart of an adult man is about five inches in length, three and a half in breadth, and two and a half inches in thickness. It is about the size of the owner's fist, and weighs from 10 to 12 ounces.

59. **The Thoracic Duct** is the main trunk of the lacteals and lymphatic vessels. It runs up from the abdomen, nearly opposite the second lumbar vertebra, to the left side of the root of the neck. It is from eighteen to twenty inches long, and about the thickness of a goose quill. It leaves the abdomen by the aortic opening in the diaphragm, ascends to the neck, then bending downwards, terminates in the left subclavian vein at the angle formed by its junction with the jugular vein.

Sc. Ex., 1868, E.—Where is the heart placed? 58 and 182. How many chambers does it contain? 194. What is the course of the blood through them? 195.

60. **The Lymphatics**, or Absorbents, are a system of vessels which drain and convey lymph. They are distributed all through the body except the brain, spinal cord, and the interior of the eye.

61. **The Spleen** (Latin, *splen*) is a soft, somewhat oval-shaped body, of a dark purplish colour. It is situated on the left side of the abdomen, immediately behind the larger (cardiac) end of the stomach, to which its concave surface is attached. Its upper convex surface is fitted to the diaphragm, which separates it from the 9th, 10th, and 11th ribs; its lower end lies over the left kidney.

62. **The Diaphragm** (Greek, *diaphragma*, from *dia*, and *phrasso*, to break off, to defend) is a large, thin, membranous, and muscular organ which stretches across the lower part of the thorax, separating it from the abdomen, of which it constitutes the roof, thus dividing the trunk into two parts. The diaphragm forms the floor of the thorax. It is attached in front to the sternum, or breast-bone, behind to the vertebral column, and on every side to the lower ribs.

Sc. Ex. 1868, E.—Give an account of the structure and uses of the diaphragm. 62 and 213.

Sc. Ex., 1869, E.—Where is the diaphragm? (62 and 182) and what office does it perform? 62 and 213.

EXPLANATION OF SOME OF THE TERMS USED IN ANIMAL PHYSIOLOGY.

63. **Abdominal Viscera.**—The stomach and intestines, liver and gall, bladder, pancreas, kidneys, &c.

64. **Afferent** (Latin, *af*, to, and *fero*, I bring).—Bringing to: applied to the sensory incarrying nerves conveying impressions from the surface to the brain and spinal cord.

65. **Albumen** (Latin, *albus*, white).—One of the flesh-forming foods: along with the gelatines, glutens, caseines, &c., it makes up the nitrogeneous diets.

66. **Aliment** (Latin, *alimentum*, from *alo*, to feed). Anything that nourishes the body.

67. **Anastomosis** (Greek, *ana*, and *stoma*, mouth).—To unite by open mouths. The ramification of one vessel into another, as an artery into another artery, or a vein into a vein. Some blood vessels are to larger ones what tributaries are to rivers; others are like the branches of a delta river issuing from and returning into the main current; the latter kind only represent anastomoses.

68. **Aorta** (Greek, *aorte*, the great artery).—The great artery proceeding from the left ventricle of the heart.

69. **Apophysis** (Greek, *apo*, from, and *phusis*, growth).—The projecting soft end or protuberance of a bone; a process of a bone.

70. **Arachnoid** (Greek, *arachne*, a spider, and *eidos*, a form).—A semi-transparent thin membrane which is spread over the brain and spinal cord, and between it and the *pia mater*.

71. **Areolar** (Latin).—Containing small spaces, and applied to the connective tissues of the body.

72. **Arteries** (Greek, *arteria,* from *aer*, air, and *tereo,* to preserve or contain).—Tubes which convey the blood from the heart to all parts of the body.

73. **Auricle** (Latin, *auricula,* diminutive of *auris,* the ear).—The name given to the two upper chambers of the heart.

74. **Backbone.**—Twenty-four vertebræ piled one upon another, which form a tube in which is placed the spinal cord.

75. **Bifurcate** (Latin, *bifurcus,* from *bis*, twice, and *furca,* a fork).—Forked; divided into two branches.

76. **Blastema** (Greek, *blastano*, to bud).—The granular, gelatinous basis of the ovum; the rudimental mass of an organ in the state of formation.

77. **Butyric** (Latin, *butyrum*, butter).—Applied to an acid obtained from butter.

78. **Cœcum** (Latin, *cœcus*, blind).—The blind intestine (*caput coli*), so named from its being prolonged inferiorly under the form of a *cul-de-sac*, or closed tube.

79. **Cancellated** (Latin, *cancellatus*, from *cancello*, to deface).—Cross-barred; cellular, as the porous structure of bones.

80. **Capillaries** (Latin, *capillaris*, from *capillus*, hair).—Fine, minute blood and lymph vessels, found in every part of the body, except the extravascular portions (hair, teeth, &c.).

81. **Cardiac Orifice** (Latin, *cardiacus*, heart).—The opening by which the œsophagus communicates with the stomach on the heart side.

82. **Carotid Arteries** (Greek, *karotides*).—Arteries which convey the blood from the aorta to the head and brain.

Sc. Ex., 1871, E.—Where are capillaries found? 80. What is their structure? 199. And of what use are they? 212.

83. **Cerebellum** (Latin).—The hinder and lower part of the brain, which directs the motor nerves.

84. **Cerebrum** (Latin).—The upper part of the brain.

85. **Cervical** (Latin, *cervix*, the neck).—Belonging to the neck, as the cervical nerves, cervical vessels.

86. **Chylification** (Greek, *chulos*, juice, humour).—The turning of the food into chyle.

87. **Chyme** (Greek, *chumos*, juice).—Food which has been acted upon by the gastric juice.

88. **Coagulation** (Latin, *coagulo*).—The act of changing from a fluid to a fixed state; setting.

89. **Coccyx** (Greek, *kokkux*).—Four little bones placed end to end at the lower extremity of the *os sacrum.*

90. **Cochlea** (Latin, *cochlea*, a snail's shell).—The third part of the labyrinth of the ear, so called from its shape.

91. **Colon** (Greek, *kolon*, a member or limb).—The second part of the large intestines.

92. **Curtain of the Soft Palate.**—That which hangs down in front of the pharynx, separating that cavity from the mouth.

93. **Cushion of Cartilage.**—That between each of the vertebræ, &c., by which they are fastened together.

94. **Cutaneous** (Latin, *cutis*, skin).—Pertaining to the skin.

95. **Deglutition** (Latin, *deglutio*, to swallow).—The act of swallowing.

96. **Dentine** (Latin, *dens*, *dentis*, a tooth).—The substance of which the teeth are chiefly made.

97. **Diastole** (Greek, *dia*, and *stello*, to set or send from).—A dilatation of the heart, auricles, and arteries; opposed to systole, or contraction.

98. **Digestion** (Latin, *digestio*, from *digero*, to dissolve).—The conversion of food into chyme, or the process of decomposing it into a new form, and thus preparing it for circulation and nourishment.

99. **Dorsal Vertebræ** (Latin, *dorsum*, the back).—Those forming the backbone, and to which the ribs are fastened. They are twelve in number.

100. **Duodenum** (Latin).—The first ten inches of the intestines.

101. **Dura Mater** (Latin).—The outer covering of the brain.

102. **Endosmose** (Greek, *endon*, within, and *osmos*, impulsion).—The process by which one fluid, gas, or liquid separated from another by a membrane mixes with it in a direction inwards from without. (See Exosmose, 107.)

103. **Epiglottis** (Greek, from *epi*, and *glotta*, the tongue).—One of the cartilages of the larynx, whose use is to cover the glottis when food or drink is passing into the stomach.

104. **Epiploon** (Greek, *epi*, and *pleo*).—The canal or omentum, a portion of the peritoneum or lining membrane of the abdomen, which covers the front, and floats as it were on the intestines.

105. **Epithelium.**—A covering membrane, formed of the same structure as epidermis, but finer and thinner: it lies upon the mucous membranes of the internal cavities.

106. **Eustachian Tubes.**—The tubes which form a communication between the internal ear and the back part of the mouth; so named after the discoverer, Eustachius.

107. **Exosmose** (Greek, *ex*, and *osmos*, impulsion).—The passage of gases, vapours, or liquids, through membranes from within outwards.

108. **Expiration** (Latin *ex*, out, and *spiro*, to breathe).—The act of breathing out.

109. **Farinaceous** (Latin, *farina*, meal).—Mealy; starchy.

110. **Fasciculus** (Latin, *fasciculus*, a little bundle). A small bundle of muscular fibres.

111. **Fibrin** (Latin, *fibra*).—That substance in the blood which is seen when it thickens or coagulates.

112. **Follicle** (Latin, *folliculus*, from *follis*, a bag or bellows).—A little sac.

113. **Foramen,** plural *foramina* (Latin).—A hole or opening by which nerves or blood vessels obtain a passage through bones.

114. **Function** (Latin, *functio* from *fungor* to perform).—The office of any particular part of animal bodies.

115. **Ganglion** (Greek, *gagglion*).—A small mass of nervous matter resembling a knot; also a conglomeration of secretory glands as in the lymphatic ganglia.

116. **Gastric** (Greek, *gaster*, the stomach).—Belonging to the stomach.

117. **Gastric Glands.**—Those glands in the mucous membrane which secrete gastric juice.

118. **Gastric Juice.**—A fluid containing hydrochloric and lactic acids and pepsine, and which is secreted by the gastric glands.

119. **Glenoid** (Greek, *glene*).—An epithet applied to some articular cavities of bones. The surface of

the scapula with which the head of the humerus is articulated, is called the *glenoid* cavity of the scapula.

120. **Glottis** (Greek, *glotta*, a tongue).—The narrow opening at the upper part of the trachea or windpipe, which, by its dilatation and contraction, contributes to the modulation of the voice.

121. **Hœmatin** (Greek, *aima*, blood).—One of the substances contained by the red corpuscles, to which their red colour is chiefly due.

122. **Ileum** (Latin, from Greek, *eileo*, to turn about). The lower portion of the small intestine.

123. **Inosculate** (Latin, *in*, and *osculatus*, from *osculor*, to kiss).—To unite by opposition or contact; to unite, as two vessels at their extremities, as one vein or artery *inosculates* with another; a vein inosculates with an artery.

124. **Insalivation** (Latin, *in*, and *saliva*).—The pouring of the saliva into the mouth, and its being mixed with the food.

125. **Inspiration** (Latin, *in* and *spiro*, to breathe).—The act of drawing air into the lungs; breathing in.

126. **Intercostal** (Latin, from *inter*, between, and *costa*, a rib).—Placed or lying between the ribs.

127. **Jejunum** (Latin, *jejunus*, hungry or empty.)—The second portion of the small intestine.

128. **Labyrinth** (Latin, *labyrinthus*).—Two cavities in the ear which are filled with a fluid like water; viz., the bony labyrinth and the membranous labyrinth.

129. **Lacteals** (Latin, *lac*, milk).—The small tubes through which the chyle passes to the thoracic duct.

130. **Lumbar Vertebræ** (Latin, *lumbus*, a loin).—Those at the back of the abdomen. They are five in number.

131. **Mastication** (Latin, *mastico*).—The breaking up of the food by the teeth.

132. **Maxillary** (Latin, *maxillaris* from *maxilla*, the jaw-bone).—Pertaining to the jaw; as the *maxillary* bones or glands.

133. **Medulla Oblongata.**—That part of the spinal cord within the cranium.

134. **Medullary** (Latin, *medullaris* from *medulla*, marrow).—Pertaining to marrow, the pith-like substances of the interior of the brain case and spinal column.

135. **Mesenteric Glands** (Greek, *mesenterion*, from *mesos*, middle, and *enteron*, intestine).—The knots of lacteals in the mesentery.

136. **Mitral Valve.**—The valve between the left auricle and left ventricle.

137. **Neurilemma** (Greek, *neuron*, a nerve, and *lemma*).—The sheath of a nerve.

138. **Œsophagus.**—The gullet which passes down behind the windpipe or trachea.

139. **Oleaginous** (Latin, *oleaginus*, from *oleum*, oil). Having the qualities of oil; oily or fatty.

140. **Olfactory Nerve** (Latin, *olfacio*, from *oleo*, to smell).—The nerve that is spread out upon the mucous membrane of the nose to receive olfactive impressions, which it conveys to the brain.

141. **Organ** (Latin, *organum*).—Any part of a living body which has a particular work or function to perform.

142. **Organs of Purification.**—The skin, lungs, and kidneys.

143. **Os Hyoides.**—The tongue bone.

144. **Osseous** (Latin, *osseus*, from os, a bone).—Bony.

145. **Pancreas** (Greek, *pan*, all, and *kreas*, flesh).—A gland of the body situated between the bottom of the stomach and the vertebræ of the loins. Its function is to secrete the pancreatic juice.

146. **Papillæ** (Latin from *pappus*, down).—Little eminences which cover the tongue and ends of the fingers.

147. **Parietal** (Latin, *paries*, a wall).—The large flat bone on the side of the head.

148.—**Parotid** (Greek, *para*, near, and *ous*, *ota*, ear). Salivary glands near the ear.

149. **Pericardium** (Greek, *peri*, around, and *kardia*, heart).—The serous membrane which encloses the heart.

150. **Peristaltic Action** (Greek, *peristaltikos*, from *peristello*, to involve).—The movement of the stomach and intestines during digestion, by which the food is turned about in the stomach and propelled down the intestines.

151. **Peritoneum or Mesentery** (Greek, *peritonaion* ; *peri*, about, and *tonoo*, to stretch).—A thin, smooth, serous membrane investing the whole internal surface of the abdomen.

152. **Perspiration** (Latin, *per*, through, and *spiro*, to breathe).—The act of perspiring or sweating.

153. **Physiology** (Greek, *phusiologia*, from *phusis*, nature, and *logos*, discourse).—The science of the functions which the various parts of the body perform during health.

154. **Pia Mater.**—The inner covering of the brain.

155. **Plasma** (Greek, from *plasso*, to form).—Liquor sanguinis, or the liquor of the blood.

156. **Pleura** (Greek, the side).—The thin, serous membrane which covers the inside of the thorax, and also invests the lungs.

157. **Pulmonary** (Latin, *pulmo*, the lungs).—Pertaining to the lungs.

158. **Pylorus** (Greek, *puloros*, from *pule*, a gate).—The lower and right orifice of the stomach.

159. **Rectum** (Latin).—The third and last part of the large intestines.

160. **Respiration** (Latin, *re*, back again, and *spiro*, to breathe).—Breathing, including inspiration and expiration.

161. **Saccharine** (Latin, *saccharum*, sugar).—Pertaining to sugar.

162. **Sacrum** (Latin).—The wedge-shaped bone on which the back-bone rests.

163. **Semilunar Valves** (Latin, *semi*, half, and *luna*, moon).—The three valves at the beginning of the pulmonary artery and aorta; so named from their half-moon shape.

164. **Sensorium** (Latin, *sensus*, *sentio*, to feel).—That part of the brain which receives the nerves of sensation.

165. **Serous Membranes.**—Membranes which line the closed cavities of the body, such as the arachnoid.

166. **Serum** (Latin).—The watery part of the blood.

167. **Sinuses** (Latin, *sinus*, an opening).—Passages in the bones of the skull and elsewhere, for the blood vessels and nerves.

168. **Spinal Cord** (Latin, *spina*).—Nervous matter found in the back-bone.

169. **Stapes** (Latin, a stirrup).—One of the bones of the internal ear, so called from its shape.

170. **Structure** (Latin, *structura*, from *struo*, to build up) —Manner of building.

171. **Subclavian** (Latin, *sub*, and *clavis*, a key).—Situated under the clavicle or collar-bone, as the *subclavian veins and arteries.*

172. **Tenacity** (Latin, *tenacitas*, from *teneo*, to hold).—The power of holding together.

173. **Tissue** (French, *tissu*, woven).—A peculiar arrangement of the fibres in an organ: the forms of tissue are—cellular or areolar, muscular, and nervous.

174. **Tricuspid Valve** (Latin, *tres*, three, and *cuspis*, a point).—The valve between the right auricle and right ventricle; so named from its shape.

175. **Uvula** (Latin).—The small conical fleshy substance which hangs down at the back of the soft palate.

176. **Vascular** (Latin, *vasculum*, a vessel).—Containing a large number of blood vessels.

177. **Veins** (French, *veine*).—Tubes, or long membranous canals which convey blood to the heart.

178. **Ventricle** (Latin, *ventriculus*, from *venter*, the belly).—The name given to the two lower chambers or cavities of the heart.

179. **Villi** (Latin, *villus*, hair).—The roots of the lacteals, which suck up or absorb the fatty portion of the chyle.

180. **Viscera** (Latin, plural of *viscus*).—The organs contained in the great cavities of the body.

181. **Viscid** (Latin, *viscidus*, from *viscus*, bird-lime).—Glutinous, sticky.

GENERAL BUILD OF THE HUMAN BODY.

182. **Structure.**—The human body is naturally divided into *head*, *trunk*, and *limbs*. The *head* consists of 22 bones, 8 *cranial* and 14 *facial*. All the latter are immovable except the *inferior maxillary* (lower jaw), which in man is single and of a horse-shoe shape. The trunk is divided into the *thorax* and *abdomen*, separated by the diaphragm, which is concave to the latter. The lower part of the abdomen is called the *pelvis*, supported from beneath by the ossa innominata, sacrum, and coccyx.

The contents of the skull are the brain, which consists of the two cerebral hemispheres, and the cerebellum, together with the parts overlapped by these. The contents of the thorax are the following viscera, heart and its vessels, and lungs with their pleura.

The abdominal viscera comprise the smaller and larger intestines, the stomach, liver, spleen, pancreas, and kidneys.

The pelvic contents are the bladder, and the termination of the rectum or larger gut.

The limbs, inferior and superior, are built upon one plan; the latter are more fitted for prehension, the former for locomotion. Each consists of 30 bones: thus, in the upper, we have humerus, radius, ulna, carpus, metacarpus, and digits (phalanges); in the lower, the following, which respectively correspond to the foregoing, femur, tibia, fibula, tarsus, metatarsus, and digits (phalanges).

Besides this inferior and superior limb correspondence, there is an external bilateral symmetry, or right and left hand similarity of construction. This is not continued in the arrangement of the enclosed viscera, though we have the two pleura, two lobes of the liver, and two kidneys, in the two halves.

Sc. Ex., 1867, E.—How are the spinal canal and the cavities of the thorax and abdomen separated from one another? and what structure divides the thoracic from the abdominal cavity? 182.

Sc. Ex., 1867, E.—What is the position of the heart, the lungs, the liver, and the kidneys? 182, 58, 55, 51 and 56.

The trunk is constructed upon the vertebral or spinal column, which consists of the bodies of 33 vertebræ, arranged in the following order :—7 cervical, 12 dorsal or costal, 12 lumbar, 5 sacral, and 4 coccygeal. The thorax is enclosed by the dorsal part of the back-bone, by the 24 ribs, and cartilages, and sternum ; the abdomen by the lumbar, sacral, and coccygeal vertebræ, and by the muscles stretching from the lower ribs to the pelvic bones.

183. **Tissues.**—The whole of this framework and its contents are enclosed in an outer skin, or integument, consisting of (*a*) an external, scaly, horny layer (*epidermis*, *cuticle*, or *scarf skin*), without blood-vessels or nerves, forming a protective covering to (*b*) an inner, dense, fibrous portion, full of nerves and blood-vessels, called the *dermis*, *cutis*, or *true skin*. At the apertures of the body (the two extremities of the alimentary canal, nostrils, &c.) this skin is continuous with a *mucous membrane*, consisting of similar layers, but of a more delicate texture. The outer one is thus nerveless and bloodless, and is called the *epithelium*. Between the outer integument and the inner mucous membrane are enclosed the muscles, bones, and cartilages, all of which are thus imbedded in *areolar*, *fibrous*, or *connective* tissue.

184. **Arrangement of Muscles.**—The muscles are so stretched upon the limbs to be moved that they can be used in *flexion* and *extension* as antagonists. Thus in the *humerus* the *biceps* flexes the radius upon the arm, while the *triceps* extends it again.

Sc. Ex., 1868, E.—What are the ribs? How many does a man possess, and what cavity do they help to enclose? 182 and 3.

Sc. Ex., 1869, E.—What is the vertebral column, and what important structures does it protect? 182.

Sc. Ex., 1867, E.—What is the difference between the dermis and the epidermis? 183.

In the trunk the muscles cover the whole parietes—outside wall of the body—before and behind, and are stretched from the clavicles and scapulas to the ribs,

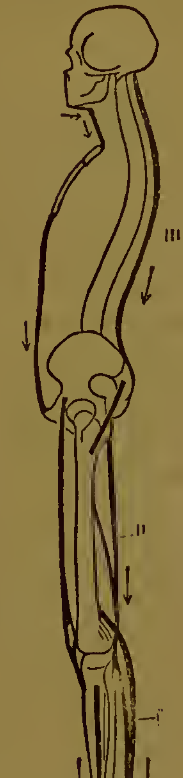

Fig. 1.—I, II, III. Muscles of calf, thigh, and spine. Those of the spine prevent the body falling forward; those of the calf pull the body into an erect posture.

and from the ribs to the pelvic bones. This general arrangement is shown in the accompanying figure, where we see the muscles of the calf prevent the body falling forward, while those of the front of the thigh draw the body to the front, any too great stretch in which direction is overcome by the muscles of the back. The total resultant is the erect posture.

CHEMICAL CONSTITUENTS OF THE BODY.

185. About one-third of all the known elements are met with in the chemical constitution of the human organism, nor is there any element in the organic which is not in the inorganic.

The *essential* elements are oxygen, hydrogen, carbon, nitrogen : all organic substances have three of these in combination at least. The *incidental* elements are sulphur, phosphorus, chloride of sodium (common salt), calcium, magnesium, iron, copper, &c. These are built up in more complex combinations than in the inorganic world, and are therefore more liable to decomposition. Between the inorganic and organic lie the materials of food, excretions, secretions, &c. Such are urea, and the fatty and oily matters, of which it may be said the more vital the processes the more the products approach the organic. The organic compounds are (1) *non-azotised*, or *non-nitrogenous*, such as cerebrine, stearine, elaine, and other fatty materials ; (2) *azotised*, or *nitrogenous*, comprising gelatine (flesh), albumen (blood), chondrine (gristle), fibrine (blood), protein (in nearly all tissues), horny, mucous, and extractive matter. *Proteids* are made up of carbon, hydrogen, nitrogen, and oxygen. *Fats* consist of carbon, hydrogen, and oxygen, with more hydrogen than is sufficient to form water, in combination with oxygen. *Sugar*, found in liver, is composed of the same three elements; but there is only enough hydrogen to form water when combined with the oxygen.

Sc. Ex., 1867, E.—When a man stands upright, how is his body retained in that position ? 184.

Sc. Ex., 1867, E.—What is a muscle, and what are the most important properties of muscle ? 184, 190, and 31.

Sc. Ex., 1870, E.—When a man stands up, by what means is his body kept in that position ? 184.

The mineral constituents of the body are comprised under the head of the *incidental* elements.

The ultimate chemical products of decay and putrefaction of the body must therefore be the elements enumerated above, or compounds made up of them.

The chief of the latter are (1) **Carbonic Acid**, derived from the union of the carbon of the body wasted in work and food materials with the oxygen absorbed by the blood in the lungs.

(2) **Urea** (made up of carbon, hydrogen, nitrogen, and oxygen), strained from the blood through the filter of the kidney, or exuded with the sensible perspiration and sweat of the skin.

(3) **Uric Acid** also filtered through the kidneys, and discharged through the ureters.

(4) **Ammonia** (NH_3), in the form of bi-phosphates, also strained through the kidneys, together with other *phosphates*, the result of nervous waste, and *sulphates*, the effect of muscular work.

The body is like the centre of a whirlpool in a river, fixed in form yet changing in constituents; ever breaking up the vegetable and animal tissues ingested as food, and resolving them into the ultimate mineral constituents from which they were derived, becoming itself changed into the same when its work is done.

GENERAL VIEW OF THE ANIMAL BODY IN ACTION.

186. During life the body is constantly undergoing a process of wasting away; "in the midst of life we are in death." Every time a muscle is called into action a tissue is used up in combustion or oxidation to supply the necessary force, and every time a nervous influence expends itself, it is with the consumption of itself. The following considerations are evidence of this statement:—

(1) The quantity of sulphates passed by the kidneys into the urine varies with the quantity of muscular work done.

Sc. Ex., 1867, E.—A man who is kept without food rapidly diminishes in weight; in what shape does the substance which he loses leave his body? 185.

(2) The same is true of the phosphates and nervous work.

(3) A man balanced in a scale-pan will constantly undergo loss of weight, unless food be taken to supply the waste.

(4) If a man be enclosed in a caoutchouc bag, moisture, urea, and animal matter will accumulate in the bag, which must under the circumstances be derived from the subject of the experiment.

(5) If dry air be inhaled, after a period it will be found charged with the moisture of respiration which has been carried on in it.

The nature of the waste products has been given when treating of the chemical constituents of the body. The compensation for the waste must be taken in as air and food.

Every time the act of respiration is performed, an interchange takes place between the oxygen of the air and the carbonic acid of the blood in the capillaries spread out upon the air-cells in the lungs; but, as about 10,000 grains more oxygen are taken in per day by this process than are given out, in combination with carbon in carbonic acid, the body is constantly absorbing this "sweeper of the animal economy," whereby fresh vitality in nerve and muscle are derived, and the processes of combustion, or chemical combination of oxygen with carbon of dead tissue, or useless food elements, is maintained, whence we derive vital force. Without this servant of the living frame, the muscles would cease to act, even if supplied with blood, as is seen in asphyxia; and the nerves would be themselves powerless to command or bear messages. In the lower orders of animal life no inconsiderable part of the aeration of the blood is carried on by absorption of oxygen through the tissues, and this takes place to some extent in man; and were it not that oxygen exists in loose chemical combination in the blood, it

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Sc. Ex., 1871, E.—What waste matters leave the body by the skin, what by the kidneys, and what by the lungs? 185, 186.

Sc. Ex., 1867, E.—What is the use of breathing? 186.

Sc. Ex., 1868, E.—How does air which has been breathed differ from pure air, and what is the cause of the difference? 186 and 212.

Sc. Ex., 1869, E.—What is oxygen? What happens if a man be insufficiently supplied with it? 186.

Sc. Ex., 1870, E.—What changes does the blood undergo in passing through the lungs? 186.

would be constantly passing off through the membranes of the body by the process of osmosis. After death oxygen becomes "lord of the body," and soon breaks up the complex structure into its primordial elements.

The air breathed out differs from that which is taken into the body, as follows :—

(1.) It has a temperature between 90° and 100°, whereas the inspired air may be warm or cold, according to the temperature of the air.

(2.) It is always well charged with moisture, which is not the case at all times with the air taken into the body.

(3.) It contains about five per cent more of carbonic acid, and five per cent less of oxygen than the external air. It also contains animal matter of a very decomposable nature.

187. **Food Stuffs.**—Food must supply whatever the body is made of, and whatever is being constantly used up in work, with the exception of oxygen supplied from the air. Accordingly we have—

(1) **Proteids**—*nitrogenous, plastic*, or *albuminous foods*, as gluten (wheat), albumen (white of egg), fibrin (in flesh), syntonin (flesh), caseine (cheese), gelatine (in membranous tissues), chondrin (gristle or cartilage).

(2) **Fats**—*oleaginous foods*. In animal and vegetable tissues. (Cocoa is 50 per cent fat.) These are for the nervous tissues.

(3) **Saccharine**, or **Amyloids**—chiefly vegetable.

(4) **Aqueous** and **Mineral**—to lubricate the tissues, keep up the equilibrium of heat and moisture, and carry off refuse. The fats and amyloids do not become tissues, but generate heat and force.

Foods may also be classified as—

(1) **Essential**—proteins, or nitrogenous, for tissues, heat, and force.

(2) **Accessory**—amyloids, fats, for heat and force only.

Sc. Ex., 1867, E.—What is the use of taking food? 185, 187.

Sc. Ex., 1868, E.—What are the different kinds of food? 187. Why is the grain of wheat good for human food (187) and the straw not?

Sc. Ex., 1869, E.—How does the air breathed out differ from that which is taken into the body, and what is the cause of the difference? 186 and 212.

188. **Sensory Organs.**—The sensations are divided into—

(1) Organic sensations (hunger, thirst, repletion, fatigue, repose, &c).

(2) Those of the five senses. These will be discussed more especially hereafter.

189. **Cilia.**—In the lower orders of creation, locomotion and prehension of food are largely carried on or assisted by ciliary action. In human physiology their functions are more restricted, but very important. It is by their action that the currents of air from the larger bronchi reach the minute air cells of the lungs, and are passed out again after having effected their needful interchange of gases; by them the mucus exuded in the bronchial tubes is passed forward to the trachea, to be exploded with violence in the act of coughing when irritative. By their means also the contents of the lachrymal sac are distributed over the inner surface of the nose to be dried up by the currents passing through from the posterior nares and pharynx. They are also to be met with in the ventricles of the brain, and in the Eustachian tubes, assisting the latter in keeping up the proper air-communication between the middle ear or tympanum and the outside atmosphere. When these can no longer act, owing to the inflammation of the tubes from severe cold, we are painfully conscious of their importance. Their motion is due to the alternate contraction of their bases (the epithelia), this is not due to nervous influence, for it takes place after the death of the body as a whole, and when the epithelium cells are separated from the basement membrane on which they rest. Yet it is harmonious, consisting either in alternation of bowing with erect action, or in circular sweeps in one direction by which the mucus is propelled by all in the same direction.

190. **Muscular Tissue.**—(1) **Smooth,** unstriated muscle consists of long, spindle-shaped fibres, each one containing a nucleus of the shape of a rod. These have no sheath and do not subdivide. They are largely met with encircling the arteries circularly, or arranged longitudinally along them; it is due to the contraction of the circular bands, under stimulus from cold or by means of the sympathetic, that the local changes in supply of blood takes place in blushing, turning pale, &c. They are also met with in the alimentary canal, where they are the instruments of the peristaltic action by which the contents of the intestine are passed along. Their function in the veins is similar to that in the arteries, but they are less abundant. They are the servants of the organic functions (with the exception of the heart) as distinguished from the higher animal processes of life ministered to by them.

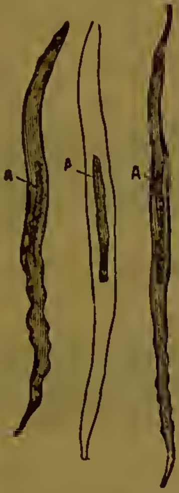

Fig. 2.—Arterial muscular fibres with nucleus. The middle one has been treated with acetic acid, to render the nucleus A more distinct.

(2) **Striated Muscle.**—This makes up the general fleshy portion of the body, and is generally found in

bundles wrapped up in connective tissue. It is richly supplied with blood vessels and nervous connections. Each fibre is covered by a sheath of strong elastic, structureless membrane (*sarcolemma*), and is made up of discs (*sarcous elements*) with alternate light spaces between their conjoined faces, to which their striated appearance is due. The fibres break up into fibrillæ with nuclei. Under the stimulus of direct irritation, or nervous influence, the sarcous elements contract, by which the length of the muscle is diminished but the absolute size is not decreased : this contraction results in a drawing together of the two ends of the muscle with their attached resistances.

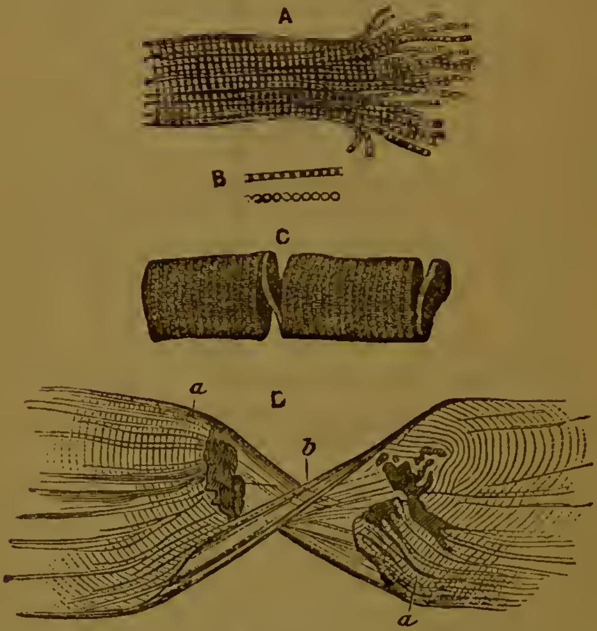

Fig. 3.—A, striated fibre and fibrillæ. B, separate fibrillæ. C, muscular discoids. D, fibre and sarcolemma.

Living muscle is of a pale yellow colour and contains

75 per cent water, but after death coagulation sets in, and we have the "death stiffening" or "rigor mortis."

191. **Nervous Tissue.**– (1) **Nerve Fibres.**—These are clear oily-looking filaments during life, but after coagulation subsequent to death they are seen to be made of a structureless membrane around an axis cylinder, with the "white substance of Schwann" between.

The olfactory nerves are really prolongations of the olfactory lobes through the *cribriform* plate of the ethmoid and not true nerve; they accordingly have no axis cylinder nor contents.

(2) **Ganglionic Corpuscles** or Nerve Cells, in brain, spinal cord, ganglia of posterior roots, and in sympathetic. These mostly consist of centres of grey matter, with white fibres interlacing them. They serve as ramifying junctions by which nervous influence is diffused and reflected.

192. **Brain and Spinal Cord.**—Under concussion of the brain a man drops powerless, but after a time possibly recovers. This temporary cessation of ordinary life is due to the cessation of the influence of the brain. Yet all motion is not due to cerebral influence, for the spinal cord may be severed, and motion may still take place in the limbs below the injury, but no sensation is felt there. It thus appears that the brain originates mental action, and is the theatre of sensation, but the spinal cord can act as a trunk to the brain and as an

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Sc. Ex., 1868, E.—What are muscles? 31 and 190. State where muscles are found. 183, 184, 190.

Sc. Ex., 1870, E.—Describe the minute structure of muscle. 184, 190, and 31.

Sc. Ex., 1871, A.—Where are plain or unstriped muscular fibres found? What purposes do they serve in the economy? In what respects differ they from striated? 190.

independent centre, converting by reflex action an impression conveyed through its afferent nerves, into an order through the efferent nerves, which is obeyed in combined muscular action.

GENERAL AND LOCAL DEATH

193. It was stated (186) that death is always taking place in the human body: death is, however, (1) *local*, constant or accidental, and (2) *general*, that of (*a*) the body, (*b*) that of the tissues.

Local death results from the individual cells of epidermis, epithelium, &c., being thrown aside when they have accomplished "like a hireling their day." In like manner the corpuscles of the blood, and the sarcous elements of the muscle, the elements of the nervous system and general tissues, even to the bones, are constantly replaced by fellow-workmen especially prepared to take their place. The only exception to this exists in the case of the cartilages, which, having been once destroyed, are never replaced.

General death takes place when (1) the body dies as a whole in consequence of the cessation of the functions of the lungs (*respiration*) and the heart (*circulation*). Death from injury to the brain is not proximate, but due to consequent stoppage of respiration and circulation. The death of the tissues does not take place for some time after the death of the body as a

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Sc. Ex., 1868, E.—Give an account of the general form of the brain, and the spinal cord, and state how they are protected. 192, 44, and 45.

Sc. Ex., 1871, E. — What is a reflex action? 234. Give examples of reflex actions. 192.

whole: so that ciliary action, rhythmical beating of the heart, peristaltic action, and muscular contraction under stimuli take place for some time longer.

CIRCULATION.

194. **The Heart** is divided into four chambers—the right and left *auricles*, and the right and left *ventricles*. The *auricles* are separated from the ventricles by valves, and the right and left sides of the heart are separated by a septum. The whole consists of striated fibres, arranged in a complicated spiral manner, so as to form a large hollow muscle. The valves between the auricle and ventricle of the left side of the heart are called the *mitral*, or *bicuspid* valves; those in the auriculo-ventricular aperture of the right side are known as the tricuspid valves. Both the mitral and tricuspid consist of delicate membranous tissue supported on a cartilaginous ring, embedded in the endocardium, or inner muscular lining of the heart. When not extended so as to cover the whole aperture they lie folded back upon this ring, but can be hooked back in a sheep's heart by a needle and their structure examined. The walls of the chambers of the heart are of varying thickness, according to the work each chamber has to perform. Thus the auricles, which merely pass the venous and arterial blood from the veins and arteries to the left and right ventricles, have thin walls; while the latter, which have to force the venous and arterialised blood to the lungs and

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Sc. Ex., 1871, A.—Describe the structure of the heart. 194. Explain the action of its valves. 194. And give an account of the causes of the sounds of the heart. 196.

general system, have thicker walls. This specially is the case with the *left ventricle*, which acts as a pump to force the blood through nearly the whole body.

195. **Course of the Blood.**—The upper and lower trunks of the venous system—the vena cava superior and inferior—open freely into the right auricle, whence the blood passes to the right ventricle. It proceeds thence through the *pulmonary arteries* to the right and left lobes of the lungs, is divided by the breaking up of the larger arteries, and, after passing through the pulmonary capillaries, is collected by the *pulmonary veins* and poured by four openings into the left auricle, whence it proceeds to the left ventricle, then to the aorta ascending and descending, which now distributes the arterial blood to the upper and lower parts of the body, to pass by the capillaries into the venous system once more.

196. **Valves.**—The right ventricle is separated from the pulmonary artery by the *semilunar* valve, similar in structure and material to the bicuspid and tricuspid valves: these are like pouches reflected from the pulmonary artery; and when the venous blood is forced through them, they are pressed back and closed by the weight of the blood. A similar contrivance separates the left ventricle from the aorta. It is the impulse of the blood upon these that give rise to the only sound

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Sc. Ex., 1868, E.—Where is the heart placed? 182 and 58. How many chambers does it contain? 194. What is the course of the blood through them? 195.

Sc. Ex., 1869, E.—What evidence is there to show that the blood is constantly in action during life? 202. How does it move and why does it move? 195.

Sc. Ex., 1870, E.—Describe the circulation of the blood. 195.

Sc. Ex., 1871, E.—In what respects does the left half of the heart differ from the right? 195.

of the heart that is capable of explanation; and so when they are hooked back in the living animal the sound referred to ceases.

. As soon as the venous blood from the right auricle has begun to fill the right ventricle, the blood getting behind the auriculo-ventricular valves forces them upwards, effectually cutting off communication with the auricle. Any tendency to flap back is prevented by tendinous chords (chordæ tendinæ), which hold these valves to the inner wall of the ventricle—the proper tension being secured by the chordæ being fastened to muscular pillars—*columnæ carneæ*—which themselves contract. A similar contrivance exists on the other side of the heart.

197. **Coronary Circulation.**—Besides this systemic circulation, we have that of the heart itself. The coronary arteries, springing from the aorta just above the semilunar valves, pass through the tissues of the heart, and being continued through their capillaries and the coronary veins, drain into the ventricle direct; this is therefore the most direct course for the blood in the whole body.

198. **The Portal Circulation** is an offset of the systemic. The arteries feeding the stomach, pancreas, spleen, and intestines, form the portal vein, *vena portæ*, which instead of passing direct into the vena cava inferior, is sent through the liver, where it breaks up into capillaries which in conjunction with the ramification of the *hepatic artery* form the *intralobular veinlets* feeding the *hepatic vein*, which is finally emptied into the *vena cava inferior*. This circulation supplies the liver with materials for the secretion of the bile.

199. **Differences of Veins, Arteries, and Capillaries.**—The capillaries differ from the veins and

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Sc. Ex., 1870, E.—How is the blood brought to the liver and how carried away from it? 198.

arteries in being much smaller, in having walls made of structureless membrane, and of mostly the same calibre throughout. The smaller arteries and veins are very similar, but the larger arteries have walls so thick and stout that they do not collapse when empty as those of the veins do: this is owing (1) to their muscular middle coat, deficient in the veins, though the latter have some muscular fibres, and (2) to their highly elastic coat. The veins, moreover, have valves opening to the heart, permitting the blood to flow only towards the heart, whereas the only arteries possessing valves are the aorta and pulmonary artery. The arteries are, moreover, smaller in calibre than the veins.

200. **Blood only Flows to the Heart.**—The blood can travel only towards the heart because any tendency to flow back from the aorta to the ventricle is checked by the semilunar valves. The shock sent through the full aorta, aided by the elastic recoil of the aorta itself, impels the fluid to the capillaries, which aid the propulsion of the blood in a way not easily explained, and when once in the veins every muscular pressure sends the blood on to the heart, the valves or pouches of the veins preventing retreat.

201. **Work of the Heart.**—The contraction of the heart by which the propulsion is carried on consist of a simultaneous contraction of the walls of both auricles, immediately following which is the simultaneous contraction of the two ventricles, succeeded by a pause. The contractions are thus rhythmical and

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Sc. Ex., 1868, A.—How do the capillaries differ from the small arteries and veins in structure and function? 199.

Sc. Ex., 1869, E.—How are arteries, capillaries, and veins distinguished from one another? 199.

Sc. Ex., 1871, E.—Where are capillaries found? 80. What is their structure? 199. And of what use are they? 212.

may be represented thus ◡ ◡ —. The state of contraction is called the *systole*, that of the relaxation is known as the *diastole*. The *beat* of the heart against the walls of the chest, between the fifth and sixth ribs, is due to the jerking of the apex of the heart upwards and forwards after the shortening of the arch of the aorta by the impulse of blood thrown against it during the ventricular systole. The pulses (radial, temporal, &c.) of the arteries are due to the recoil of the elastic tissue of the arteries, after the shock sent through the blood by the ventricular discharge. Delicate experiments also prove the existence of the shock itself, but this is soon dissipated by the branching out of the arteries into the capillaries. If an artery be cut the blood will be seen to flow out jerkingly: this is due to the same cause as the pulse, since the elastic reaction of the artery successively takes place, propelling the blood from the orifice in intermitting streams.

202. **Evidence of the circulation** in the body is derived thus:—

(1) In frogs and other creatures covered with transparent integuments the actual flow can be observed by means of the microscope.

(2) If the finger be pressed on a vein the blood may be seen to collect in front of the valves, and on the finger being withdrawn the flow is resumed.

(3) Poisons injected into a vein immediately find their way to the heart, stopping the heart's action.

(4) Blushing and turning pale under nervous excitement can be proved by experiment to be due to cessation and sudden stimulating of the sympathetic nerves. These command the muscular fibres of the arteries, and are called *vaso-motor* nerves. When they

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Sc. Ex., 1870, E.—What is the pulse? 201. Why is there usually no pulse in the veins? 199.

cause contraction of the calibre, paling takes place. Blushing arises when their functions are checked by separation.

203. **The nervous connections** of the heart are maintained by—

(1) **Ganglia.**—Masses of cells in its own substance, producing the regular rhythm of the ordinary contractions. These may take place out of the body.

(2) **Sympathetic.**—Increasing the action, as in palpitation.

(3) **Pneumogastric.**—Causing sudden cessation of action.

THE BLOOD.

204. **Blood** when first drawn from the body is clear, of a pale red colour, and of the same character throughout. The microscope shows, however, a number of yellow particles in a colourless fluid, which soon cluster into patches. These are the *corpuscles* in the *plasma*. In a very short time the blood coagulates.

205. **Corpuscles** are red and white or colourless. The former are the more numerous. They are very small; $\frac{1}{3200}$ inch in diameter; 10,000,000 would cover one square inch of surface; 70,000,000,000 would make one cubic inch. They are flattened discs with hollowed faces, so flexible and elastic that they can squeeze through the smallest capillaries and resume their shape when they have passed through. They

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Sc. Ex., 1871, A.—State fully the evidence of the circulation of the blood. 202.

Sc. Ex., 1871, E.—Of what use are the valves in the veins? 199. How can you illustrate their use on the living body? 202.

contain a fluid colouring matter called hæmoglobin, consisting of hæmatin and globulin. Their shape can be altered by changing the density of the plasma in which they float; if water be added it will penetrate through their sac walls and swell the discs; if the density of the plasma be increased, the contents of the discs will pass into the plasma, leaving the corpuscles more flattened

The colourless are larger than the red, $\frac{1}{2500}$ inch in diameter, of irregular changing shape. Their thin walls contain a nucleus inside a clear or granular fluid. They thus form *nucleated cells,* like the lower forms of life in stagnant waters. When the wall bursts and sets free the nucleus we have the red corpuscle. The colourless corpuscles are themselves derived from the constituents of the food, the *lymph-corpuscles.*

After death the red corpuscles cohere like rouleaux of coin, forming a mesh, enclosing stray corpuscles.

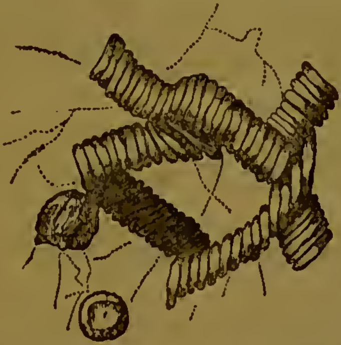

Fig. 4.—Red corpuscles in rouleaux, meshed in fibre threads.

(206.) This is the cause of the appearance of the patches referred to in paragraph 204. The hæmoglobin sometimes separates into its constituents in crystals of a prismatic form. This may be artificially produced by exposing a drop of blood to the air, moistening it, and breathing upon it, when the blood crystals will gradually brighten. The corpuscles are carriers of oxygen and carbonic acid to and from the lungs.

206. **Coagulation** is due to the setting of the fibrine of the blood, entangling the corpuscles as they fall to the bottom of the vessel in which the blood is contained, owing to their greater weight. The blood separates into a pale yellow fluid, called *serum*, and a half solidified mass, called the *clot*, or *crassamentum*. It is the latter that is made up of fibrine and corpuscles.

This coagulation is modified by the following particulars :—

(*a.*) *Living matter.*—All the while the blood is in contact with living tissues (in the veins, arteries, and capillaries) it resists coagulation. Contact with dead matter, as in beating it with twigs, drawing it into a vessel, &c., aids the setting process.

(*b.*) *Saline* matters prevent coagulation.

(*c.*) A very low temperature retards or prevents the setting and conversely a high temperature hastens it.

This coagulation is not a vital process, but depends on the physical and chemical properties of the blood. It is due to the mutual action of the fibrinogen and globulin of the blood.

The specific gravity of the blood is 1055, the temperature about 100° F., more in fevers, less in low diseases.

207. **Composition of the Blood** :—

Water	79
Corpuscles........................	12
Albumen	6
Saline, fat, saccharine, fibrine, and organic waste............	3
	100

Sc. Ex., 1871, E.—What is the nature of the corpuscles of the blood. What are their uses ? 205.

Sc. Ex., 1867, E.—Why is the blood red (205), and why does blood drawn from the body settle at first into a jelly, and afterwards into a red, solid, and a colourless fluid part ? 204, 206.

There are thus 79 per cent liquid, and 21 per cent solid parts in the blood.

Besides these, *gases*, to the amount of half the volume of the blood, are held in solution; chiefly nitrogen, carbonic acid, and oxygen. There is always more carbonic acid in the blood than oxygen; but relatively less in the arterial than in the venous blood. The oxygen is held in loose chemical combination, since pyrogallic acid, which has great affinity for it, is not oxidated by passing through the blood; and since otherwise it would permeate by osmosis through the living membranes.

The corpuscles contain the oleaginous matters, and the phosphates, iron and potash; the liquor-sanguinis, the chlorine and soda.

208. Functions of the Blood:—

(1) To carry nourishment to all the tissues of the body: to build up the wasted muscular and nervous structures.

(2) To carry off the waste from the capillaries to the secreting organs to be reorganised or passed off as effete matter.

(3) To regulate the distribution of heat through the body. The blood is a hot fluid, the heat of which is maintained by the oxidation of waste tissue and food material. When local causes, cold at the surface, &c., have lowered the temperature, the constant circulation prevents mischief.

209. **Lymph.**—All parts of the body, except the brain, spinal cord, eyeballs, gristles, bones, and tendons, are supplied with lymph-capillaries as they are with blood-capillaries. These have valves and ramify in glands, whence new trunks arise. They

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Sc. Ex., 1869, E.—What is the temperature of the blood? 206. How is the warmth of the blood maintained? 208.

pour their contents into the *thoracic duct* lying in front of the back bone. The lower part of this duct is the *receptacle or cistern of the chyle.*

Besides the lymphatic system proper, there are the lacteals, which are the lymphatics of the intestine: after a meal containing fatty matter these are distended with a milky fluid called *chyle.* This is absorbed by blind prolongations of the lacteals into the villi of the intestine. The lacteals unite into a network lying on the mesentery (a membrane which suspends the small intestine to the back wall of the abdomen), and the glands through which the trunks lead are hence called the *mesenteric glands.*

The lymph is like blood, an alkaline fluid, consisting of plasma and corpuscles, coagulating by the separation of fibrine from the corpuscles, but differs in that

(1) All its corpuscles are colourless.

(2) It contains only 5 per cent of solid matters.

RESPIRATION.

210. **Differences between Arterial and Venous Blood**—Blood taken from an artery has a bright scarlet colour, whereas that from a vein is of a dark purplish hue; the former has comparatively more oxygen in it than the latter, but the difference as regards solid and fluid constituents is very small, though generally arterial blood contains more water and fatty matter. The cause of the difference in colour is probably due in part to the flattening of the red corpuscles after taking in fresh supplies of oxygen at the lungs, in consequence of which they reflect light more strongly than when they are distended with carbonic acid. Again, as solutions of hœmoglobin or blood crystals brighten under the increase of oxygen, even when the corpuscles are absent, this has somewhat to do with the question.

211. **Conversion of Venous into Arterial Blood.**—Venous blood separated by a thin membrane

from oxygen, or a fluid containing more oxygen than itself, becomes arterialised, that is, an interchange through the membrane takes place between the two gases, the rapidity of the exchange varying inversely as the square root of the density. This may be observed by exposing venous blood in a bladder to the action of the air, or by leaving it in free communication with the atmosphere, when it will be seen that the exposed surface becomes brighter in colour.

The foregoing account has to be modified by the following considerations :—

(1) The oxygen is loosely *combined* with the corpuscles.

(2) The carbonic acid is similarly combined with saline constituents, and

(3) Moist membranes dissolve carbonic acid more than oxygen in transmission.

212. **Change in the Capillaries.**—The interchange alluded to above takes place in the capillaries of the lungs. This is proved by the following considerations :—

(1) If a ligature be tied across the windpipe then the blood remains venous in the whole heart.

(2) Testing inspired and expired air shows that the one has lost oxygen and the other gained carbonic acid. The contrary change takes place in the systemic capillaries ; here carbonic acid is poured into the blood and oxygen is absorbed by the living tissues. Another difference between inspired and expired air lies in the

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Sc. Ex., 1871, E.—Describe fully the changes which the blood undergoes in passing through the capillaries of the lungs (210, 211), the kidneys (217), and the skin.

Sc. Ex, 1868, E.—How does air which has been breathed differ from pure air, and what is the cause of the difference ! 186 and 212.

Sc. Ex., 1869, E.—How does the air breathed out differ from that which is taken into the body, and what is the cause of the difference ? 186 and 212.

fact that whatever may be the temperature or dryness of the air inhaled, that given out is made warmer and moister from contact with the membranes of the trachea and bronchi. There is, moreover, a small amount of animal matter of a highly decomposable character in expired air, especially where the function of respiration is imperfectly carried on.

213. **Respiratory Movements.** — Behind the mouth lies the *pharynx*, communicating with the external air by (1) the nasal passages or *posterior nares*, and (2) by the mouth. Immediately behind the tongue is the *glottis*, which is a narrow opening to the trachea, covered by a lid or valve, the *epiglottis*, the boundaries of which are formed by the *vocal chords* or *ligaments*. The glottis opens into a chamber with cartilaginous walls, the larynx. The trachea is fortified by hoops of cartilage, incomplete behind where they join the gullet. It branches into bronchi, which break up in each lung into bronchial tubes. In the latter the cartilaginous hoops gradually disappear, the walls becoming muscular and membranous instead. These terminate in air cells with sacculated walls on which the capillaries are festooned—it is through this membranous partition that the interchange of gases between the air and blood takes place, making the essential act of respiration.

The mechanism employed consists of—

(1) Elasticity of the texture of the lungs—this is a constant force; and

(2) The mobility of the sides (ribs), and bottom (diaphragm) of the closed cavity of the chest (thorax).

Respiration is *diaphragmatic* and *costal.*

Sc. Ex., 1868, E.—Give an account of the structure and uses of the diaphragm. 213 and 62.

Sc. Ex., 1869, E.—Where is the diaphragm? 182 and 62, and what office does it perform? 213 and 62.

In diaphragmatic respiration the muscular pillars of the diaphragm contract, and so reduce the convexity of the diaphragm, thereby increasing the size of the thoracic cavity from top to bottom; and, as no vacuum can exist there, the lungs become inflated, and the involuntary act of inspiration is performed. At the same time the *costal* respiratory action takes place. The external intercostal muscles which pass slantingly forwards and downwards from the upper to the lower ribs, contract and raise the ribs, whereby the thoracic cavity is increased in its dimensions from front to back, and the lungs as before become more inflated to fill up the space thus provided. In expiration the diaphragm is pushed upwards by the pressure of the viscera from beneath, urged upwards by the muscular contraction of the walls of the abdomen. This act is also assisted by the internal intercostal muscles, which pass from rib to rib transversely to the externals, and pull the ribs down. The combined result is seen in expiration.

Auxiliary to the foregoing are the following:—

(1) Muscles passing from the shoulder bones to the ribs assist in raising up the ribs in inspiration.

(2) Muscles in the pelvis help the internal intercostals in pulling the ribs downwards.

(3) The ribs also fall by their own weight and elasticity.

214. **Asphyxia** takes place when a man is strangled, drowned, choked, or in any other way prevented from inspiring sufficiently pure air. The face becomes black, the veins turgid, and insensibility, generally accompanied by convulsion, ensues.

This result might accrue from either of two causes—

(1) Deprivation of oxygen, termed *oxygen starvation*; or,

(2) Accumulation of carbonic acid, *carbonic acid poisoning*; or the latter might be a mere negative

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Sc. Ex., 1870, A.—Give an account of the movements of the walls of the chest, of the diaphragm, and of the course of the air in ordinary respiration. 213.

Sc. Ex., 1871, E.—What is meant by inspiration and expiration? How are they brought about? 213.

cause, the accumulation of carbonic acid in the air being generally accompanied by a diminution of the oxygen. If, however, fresh supplies of the latter gas are artificially brought in, the deleterious effects of carbonic acid are immensely decreased.

The first effect of the asphyxiating process is to block up the pulmonary; the second, the systemic circulation. The lungs, right auricle and right ventricle, no longer send the blood through them, so that they become gorged and paralysed; while the left auricle and ventricle of course are emptied of their contents.

215. Accompaniments of Respiration.

(1) *Respiratory Sounds, Murmurs.*—These are loudest over the bronchi, and are produced by the motion of the air in expiration and inspiration.

(2) *Effect on Circulation.*—Under inspiration the heart and vessels of the thorax suffer less pressure from the atmosphere than the other parts of the body, owing to the elasticity of the lung tissue which partly reacts against this pressure, so that if no valves existed in the aorta and pulmonary artery the blood would be sucked into the heart.

(3) *Residual Air* is that which is left in the lungs after a more than ordinary expiration—about 100 cubic inches.

(4) *Supplemental Air* is that which is left after an ordinary expiration—about 100 cubic inches.

(5) *Tidal Air* is that which is passed in and out in ordinary respiration—about 30 cubic inches.

(6) *Complemental Air* is that taken in beyond this in the deepest possible inspiration—about 100 cubic inches.

Sc. Ex., 1871, A.—Describe the organ of smell. How are sniffing and sneezing effected? 216 and 237.

216. **Control of Respiration.**—The glottis is subject to nerves springing from the medulla oblongata, which must be regarded as the respiratory centre of this mode of reflex action. The pneumogastric regulates the muscles of the smaller bronchial tubes. Sighing is an involuntary, deep, and prolonged inspiration, after the attention has been so engaged as to neglect the premonitory symptoms of want of air.

Sniffing is a rapid inspiration through the nostrils; the air passing below the inferior turbinal or spongy bone, proceeds through the posterior nares to the pharynx and trachea. In coughing, the glottis is closed, and then violently forced open, to the expulsion of the irritant which has given rise to the act.

URINARY SYSTEM.

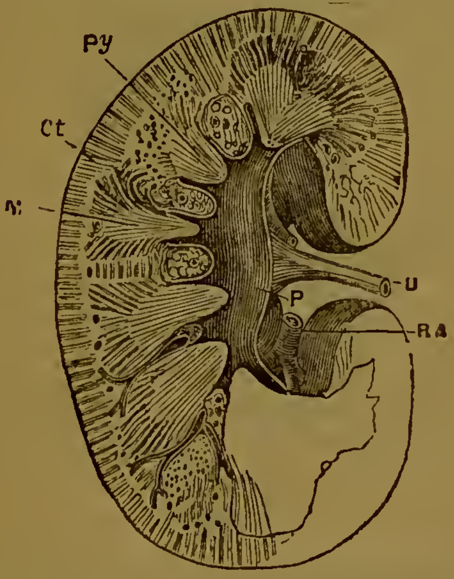

Fig 5.—Vertical section of kidney. Ct, cortical part. M, the medulla. P, the pelvic cavity. U, the ureter R A, renal artery. Py, a pyramid.

217. **Kidneys.**—The two kidneys lie at the back of the abdomen, on each side of the lumbar part of the spine. From the middle of the concave side (*hilus*) a long tube (*ureter*) proceeds to the bladder. The ureters open side by side close to one another, in the posterior part of the bladder.

From the bladder the urethra conducts the contents to be discharged. The ureters widen out at their upper extremities into basin-like cavities, the pelves of the kidney: into these two projections called pyramids arise, whose summits have small openings, the terminations of the *tubuli*. The latter lie in parallel bundles, and subsequently radiate towards the outer surface of the kidney, giving a *medullary* aspect to the interior compared with the *cortical* surface of the organ. Most of these tubes ramify in capsules, the *malpighian capsules* fed by twigs of the renal artery. It is in this *glomerulus* of looped capillaries that, under pressure from behind, the urine is filtered into the ureters—minute veins carrying off the blood from the capsules after this process has been accomplished.

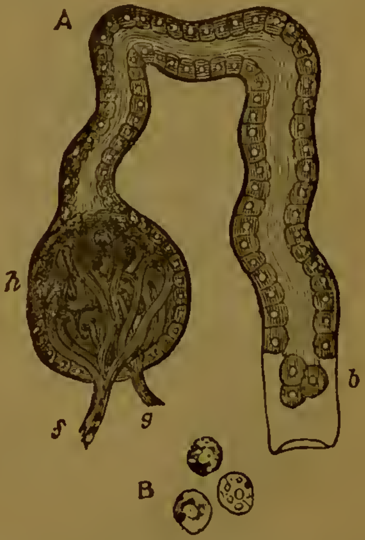

Fig. 6.—A, Malpighian capsule. *h*, a glomerulus. *b*, beginning of the tubule. *f*, artery. *g* vein. B, the epithelium magnified.

218. **Urine** has an acid reaction, and consists of water, urea, uric acid, animal products, colouring matters, and saline and gaseous products in solution. The amount and quality vary according to time of day, temperature, moisture in the air, fasting or replete state of alimentary canal, and the nature of the food.

Urea and uric acid are both compounds of carbon, hydrogen, nitrogen, and oxygen, the former being the more soluble in water and more abundant.

219. **The Bladder** is an oval bag in the pelvis. Its walls contain unstriped muscular fibre, and it is lined by mucous membrane, and coated on the outside by peritoneum. It has circular fibres; a sphincter, around the opening of the urethra, so that the contents may be retained until they have become burdensome, when the muscles of the walls contract, the sphincter relaxes, and the discharge is effected.

SKIN.

220. **Perspiration.**—The skin is a source of constant loss to the blood, excreting water, carbonic acid, and a small quantity of urea. The moisture ordinarily extracted is invisible, and is known as the *insensible perspiration.* Violent exercise, emotion, and a hot and moist atmosphere render this visible as *sweat.* This is acid, and contains fatty matters from the blood itself, and from the sebaceous glands specially provided in the cuticle for secretion of fatty matter from the capillaries of the skin. Besides the moisture which

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Sc. Ex., 1868, A.—What are the structure and functions of the kidneys? 217.

Sc. Ex., 1869, E.—Where are the kidneys (182, 217,) and what functions do they perform? 217.

exudes from the integument proper, we have the products of the *sweat glands* all over the body; the tubes of these are about one-fourth of an inch long, and their inner coiled cords are interlaced with capillaries. Their number varies, being about 400 to the square inch on the back and neck, but 2,000 to 3,000 on the palm and sole: the total number amounts to about two and a quarter millions, which would extend 28 miles. They are subject to the sympathetic system, and therefore vary in rapidity of function, according to emotion, &c. The sweat consists of water, carbonic acid, urea, animal matters, fatty matters, and scales of epidermis.

LIVER.

221. **The Liver** is a constant source of loss and gain to the blood.

(1) *Loss:* it separates the bile and throws it into the intestine.

(2) *Gain:* it elaborates *glycogen*, which passes very readily into glucose or liver sugar, carried off to the lungs. This glycogen is formed out of all kinds of food, and may be found in the liver after it has been taken out of the body and well washed with water. Branches of the hepatic artery, portal vein, and bile duct from the gall bladder, accompany each other into the substance of the liver branching out into capillaries, which traverse the smallest divisions of the liver, the *lobules*. Each lobule is a polygonal cell, about the size of a grain of millet seed, and lies upon a branch of the hepatic vein, its capillaries pouring their contents into the intralobular veinlet

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Sc. Ex., 1870, E.—What is sweat, and how is it excreted? 220.

proceeding to the hepatic vein. Thus the portal vein, vena porta, supplies the secretions of the liver, while the hepatic artery nourishes the tissues, the drainage of both being carried into the hepatic vein, and so into the vena cava.

222. **Bile** is a highly alkaline fluid, consisting of water and *biline* (glycocholate of soda, taurocholate of soda) and cholesterine, together with colouring matter. Its uses are the following :—

(1) It aids excrementition, part being excreted and part reused.

(2) Acts as purgative ; by exciting muscular contraction in intestine, and by exciting the glands to secrete.

(3) It is an antiseptic, checking decomposition already begun in the food.

(4) It emulsifies fatty foods.

The blood leaving the liver by the hepatic vein contains less water and fibrin than that brought to the liver, for it is these substances chiefly that make up the bile, but it contains more colourless corpuscles and liver sugar, which is sent to the lungs for respiration.

The bile is passed into the duodenum during digestion, but at other times is stored in the gall bladder till wanted.

223. **Heat of the Body: Production.**—The sources of heat in the body are purely chemical, and result from the oxidation of waste tissues and useless materials of food, and the combination of the excess of oxygen taken in per day (above that given out in combination with carbon in carbonic acid) with the solid constituents of the body and food, resulting in the

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Sc. Ex., 1871, A.—Give an account of the structure of the liver. 218 and 51. State what is known concerning the formation of bile and of glycogen. 221 and 222.

Sc. Ex., 1871, E.—Where is the bile formed ? 198, 221. What becomes of it, and what are its uses ? 222.

formation of the saline secretions of the kidneys, &c. Every time a muscle contracts, or a molecular change takes place in nerve tissue, force becomes correlated into heat.

Distribution.—As the heat is thus generated in different parts of the body, and as much is being constantly lost at the free surfaces of the body which must be immediately replaced, a distributing apparatus is provided in the circulation, which may be compared to the hot water of a heating apparatus, carrying an equalised temperature to all parts of the economy. The only instance where the parallel fails is in the matter of *Regulation*, for the circulation is self regulative, or at least in intimate alliance with the nervous system. Cold has the effect of increasing the activity of the vaso motor nerves which consequently contract the calibres of the pipes containing the blood, and so check undue loss of heat, by preventing perspiration. The function of perspiration keeps the heat of the body uniform, for when the external temperature is high the capillaries give out copious exudations upon the skin, and the evaporation of these withdraw heat from the body locking it up as latent heat in the vapour.

ALIMENTATION.

224. **Foods.**—The amount of dry solid foods required per day by an average man is 8,000 grains, with 10,000 grains of oxygen. The dry solid excrement will weigh 800 grains, the rest of the 8,000 grains being passed off through the lungs, skin, and kidneys in union with the 10,000 grains of oxygen.

The foods have already been classified. (187).

The body is composed of carbon, nitrogen, oxygen, and hydrogen, so that protein is absolutely necessary, or death from nitrogen starvation would take place. A man on the average excretes about 300 grains of nitrogen and 4,000 grains of carbon daily, so it is necessary to select such foods as not only give 300 grains of nitrogen for daily use, but such as will also yield 4,000 grains of carbon. Thus it would require 4 lbs. of fatless meat to yield the above, while 1 lb. of meat will give the necessary amount of nitrogen, and the carbon could be better supplied from half a pound of fat, or a pound of sugar, or two pounds of bread. Far less waste of power would arise from the digestion of either of the three last mentioned than from that of the three extra lbs. of meat required. Hence arises the true economy of a mixed diet, for it is possible that the bodily powers may be so exhausted in using up such an uneconomical diet as 4 lbs. of meat daily, that it should become bankrupt before it could realise its assets.

225. Destination of Foods.

(1) **Proteids.**—These are the tissue formers in a special sense, though they also are heat formers by changing into amyloids in the liver. The proximate effect of these is the growth and maintenance of tissue; the ultimate being the evolution of force and generation of heat. They are not affected by the saliva of the mouth, but undergo gastric digestion, the *pepsine* of the gastric juice changing them into *peptones* or *albuminose*, to facilitate their absorption into the blood vessels in the coats of the stomach. This albuminose in passing through the liver is elaborated into albumen for the tissues. The remainder of the albuminous constituents of the food, not absorbed by the blood vessels of the stomach, escape through the pylorus into the duodenum, and are there taken up into the blood and so passed through the portal circulation.

(2) **Fats.**—These also undergo no change in the

mouth, nor in the stomach, but are emulsified, saponified, or broken up into excessively minute particles by the interaction of the bile and pancreatine or pancreatic juice sent by the pancreas through the common duct to the duodenum. In the smaller intestine we find internal foldings or corrugations of the mucous membrane, called valvulæ conniventes, in and between which are minute prolongations called villi. In each of these is a lacteal radicle, meshed in capillaries, and surrounded by epithelial cells. These villi absorb the emulsified fats, and pass them through the mesenteric glands, where they are more highly organised. They are thus stored up in the body generally as fat cells, or specially laid up in the liver, to be in all cases used up for generation of heat by oxidation by means of respiration.

(3) **Amyloids.**—These undergo a change in the mouth. The ptyalin, which is the essential agent in the saliva secreted by the parotid, sublingual, and submaxillary glands of the mouth, changes the starch into dextrine and grape sugar. In this changed state the foods pass through the stomach unaffected by gastric digestion, and in the duodenum are acted on by the pancreatine, which completes the operation commenced by the saliva. They are used up in the generation of force and heat.

(4) **Mineral Foods.**—These are distributed in solution or chemical combination to the blood, bones, and other tissues where they are found, being absorbed by the blood vessels of the stomach and intestines.

226. Digestive Secretions.

(*a*.) **Saliva.**—Lying immediately in front of the ears are the parotid glands—racemose—and covered over by twigs of the arteries supplying the face. Their ducts open on the inside of the cheeks, near the second upper molar. The submaxillary lies between the inferior maxillary (lower jaw) and the bottom of the tongue, while the sublingual is on the same level, but more to the front; their ducts open beneath the tongue. The saliva secreted by these three glands answers the following purposes :—

(1.) *Chemical.*—Acts as a ferment by means of its ptyalin—a nitrogenous fluid, turning the starch to sugar.

(2.) *Mechanical.*—The bolus of the food is made to pass into the pharynx the more easily for being coated by saliva.

(3.) They *lubricatc* the mouth for purposes of articulation

(*b.*) **Gastric Juice.**—Multitudes of small, simple glands open into the stomach from its mucous membranes. Among these are others more complicated, with blind, subdivided terminations, called *peptic* glands, which secrete the gastric juice. This secretion consists essentially of hydrochloric and lactic acid, with *pepsin.* It is the latter constituent which changes the proteids into *peptones.* By continual rolling about from the contraction of the circular and longitudinal muscles of the walls of the stomach, the food is reduced to *chyme,* in which state it passes through the *pylorus* into the duodenum.

(*c.*) **Pancreatine.**—The pancreas is fastened on the spine, and lies below the stomach. It is a racemose gland, and secretes pancreatic juice during digestion only. This is sent through the common duct to the duodenum, where it

(1.) *Emulsifies the fats* for absorption by the villi, and

(2.) Turns *starch* into grape sugar and dextrine.

Sc. Ex., 1868, E.—What is the saliva, and where is it formed? 225, 226.

Sc. Ex., 1871, E.—What is the nature of the gastric juice? On what parts of the food does it act? 226.

227. **Absorption.**—It has thus been seen that the principal absorbents are the blood vessels of the stomach for liquids, albuminous foods, and solutions; that the blood vessels of the portal system absorb the amyloids in the intestines, after having been acted on by the saliva and pancreatine; and that the villi are the absorbents for fatty matters, which are elaborated into chyle and lymph-corpuscles in the mesenteric glands. It only remains to add generally that saliva solutions pass with facility through such colloidal membranes as the stomach, which give no passage, however, to colloids like themselves. It must be borne in mind that these are not the only auxiliaries in digestion, but the most important. Besides these we may enumerate—

(1) *Lieberkuhn's* glands, dippings down of the mucous membrane of the small intestine.

(2) *Brunner's* glands, which secrete a juice similar to pancreatine and pytaline.

(3) *Peyer's* glands, scattered and in groups, supposed to act as lymphatics or absorbents.

After intestinal digestion the innutritious matter of the chyle is passed along the smaller and large intestine, by the peristaltic contraction of the circular involuntary muscles above the food, and the longitudinal contraction which gives a vermicular progression to the extremity of the rectum.

228. **Mechanical Processes of Digestion**:—

(a) **Mastication** is effected by means of the teeth. In early infancy these consist of capsules imbedded in the dense mucous membrane of the jaw, which receive aggregations of dentine and absorb the mucous membrane above them by pressure in the process of "cutting

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Sc. Ex., 1869, E.—How does the nutritious matter of the food get into the blood? 227.

the teeth." These are at first twenty in number, and are known as the "milk teeth;" they subsequently are replaced as the jaw lengthens by 32 teeth arranged in the following order, in the four quadrants into which the semicircular arc formed by them may be divided.

2 *Incisor* or cutting teeth, with sharp edges.

1 *Canine,* with longer fang.

2 *Bicuspid* or false molars with double fangs, and

3 *Tricuspid, molar,* or true grinders at the back.

The enamel is the hardest substance in the body, as it consists of 98 per cent of earthy matter. Each tooth consists of a crown, neck, and one or more fangs, with a pulp cavity inside supplied with nerves. The bulk of the tooth consists of *dentine,* dense, calcified, and without the lacunæ and canaliculi of bone; the crowns are covered with enamel in hexagonal prisms and the fangs with *cement.*

(b) **Deglutition** is performed in the following stages.

(1) The tongue's longitudinal fibres contract; it is also further drawn back by muscles, it is at the same time drawn to the roof, and thus the food on it is taken to the anterior palatine arch.

(2) The tongue is drawn back still further, while the larynx is pulled up and closed by the epiglottis, at the same time that the posterior nares are closed by

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Sc. Ex., 1868, E.—Why are teeth hard? How many sorts of teeth are there? 228, and 261.

Sc. Ex., 1870, E.—What is the number of the teeth, and of what substances are they composed? 228, and 261.

Sc. Ex., 1870, E.—When a piece of bread is eaten, what change does it undergo in the mouth and stomach? 225, 226, 227, 228.

the soft curtain of the velum palate, the food then slips over the drawbridge of the epiglottis into the œsophagus.

(3.) The circular and longitudinal constrictor muscles of the gullet contract on the food, and propel it into the stomach.

ANIMAL MECHANICS.

229. **Motion.**—Much of the motion and locomotion of the human body is effected by means of the principle of the lever.

These are of three kinds :—

The **first** has the *fulcrum* between the *power* and *weight;*

The **second** has the *weight* between the *power* and *fulcrum;*

The **third** has the *power* between the *fulcrum* and *weight.*

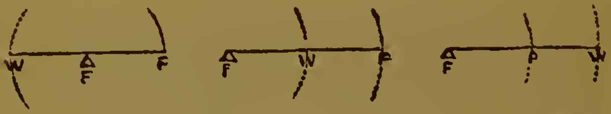

Fig. 7.—Levers I, II, and III. F, fulcrum. P, power. W, weigh.

The following are examples of the three kinds :—

1st kind (*a*).—Skull on the atlas as fulcrum, nodding on the occipital condyles.

(*b*)—Pelvis on the head of the femur as fulcrum.

2nd kind (*a*).—Femur bent up in hopping.

(*b*)—Rib depressed in expiration.

3rd kind (*a*).—Flexion of fore-arm, or arm with weight in hand.

(*b*)—Extension of leg on the thigh.

230. **Joints** are of two kinds, *perfect* and *imperfect.* The *perfect* have their opposed faces covered with cartilage, and are enclosed in a sac lining the cartilage and walls of the joints, and secreting synovia. Sometimes the opposed surfaces are separated by laminæ of inter-articular cartilage.

The *imperfect* joints allow no rotatory motion, but are connected by continuous cartilages or ligaments, moving only as these structures permit: such are the bodies of the vertebræ, and the ileum, ischium, and pubis in the pelvis.

Ball and Socket Joints.—In these the ball of the one bone plays in a deep or shallow cup or socket of the other, the extent of motion depending on the depth of the cup; examples of this are seen in the head of the humerus and cup of the shoulder blade; and in the head of the femur, and the cup or acetabulum of the haunch bone; this cup is deeper than that of the shoulder.

Hinge Joint.—These are single or double. The single have the cylindrical head of one bone fitting into the socket of the other, permitting motion only in one plane, perpendicular to the axis of the cylinder, as of a door on its hinges; an example of this may be seen in the elbow. In the double-hinge joint, each surface is concave in one direction and convex in another at right angles to this, so that one bone is articulated into the other as a man in a saddle is articulated to the horse; see the metacarpus of the thumb thus articulated with the wrist.

Sc. Ex., 1868, E.—What is a joint? 42. In what way does the hip joint differ from the elbow joint? 230.

Sc. Ex., 1869, E.—What is a joint? 42. Give examples of ball and socket joints, and of hinge joints. 230.

Sc. Ex., 1871, E.—Give an account of the structure of any hinge joint in the human body, and explain its action. 230.

A Pivot Joint is explained by its name. Either one bone furnishes a pivot on which the other turns, as the atlas on the odontoid peg of the axis, or itself turns on its own axis resting on another bone, as in the radius turning on the ulna.

231. **Ligaments.**—The moving surfaces of the joints are kept in place by strong fibrous capsules surrounding the joint on all sides, in cases of ball and socket joints; or by *lateral* ligaments in the case of hinge joints. In some cases the ligaments are placed within the joint, as the *crucial* of the knee and the round ligament of the acetabulum. *Check* ligaments are such as those from the odontoid peg to the occipital foramen, which prevent the too extensive rotation of the skull upon the peg.

232. **Movement.**—The different kinds of motion performed are the following:—

(1) *Flexion*, when a limb is bent, as of forearm or arm.

(2) *Extension*, when the limb is straightened out again.

(3) *Abduction*, when the limb is taken out of the middle line.

(4) *Adduction*, when it is brought back.

(5) *Rotation*, when the limb turns on its own axis.

(6) *Circumduction*, when it swings like a conical pendulum. The ligaments keep the joints in their places; the tendons form the origin, or insertions of the muscles; both consist of dense fibrous tissue.

Sc. Ex., 1868, E.—What is the difference between tendon, ligament, and cartilage? 231, 232, 28, 29, and 30.

Sc. Ex., 1871, E.—What are tendons? Of what use are they? 231, 232, and 28.

PRODUCTION OF VOICE.

233. **The essentials to voice are:—**

(*a*) Existence of vocal chords, or ligaments.

(*b*) Parallelism of the edges of these chords.

(*c*) A certain and variable degree of tightness of the chords.

(*d*) A current of air between their parallel edges sufficiently powerful to make them vibrate.

(*e*) The action of lips and tongue to modify the sounds thus produced into speech.

The vocal chords are elastic fibrous tissues, with broad bases fixed to the larynx, and having sharp free edges. They are fastened behind to the *arytenoid* cartilages, and in front to the *thyroid* cartilage, forming the letter V with the point to the front. The thyroid is seen to be a broad plate of gristle, bent into

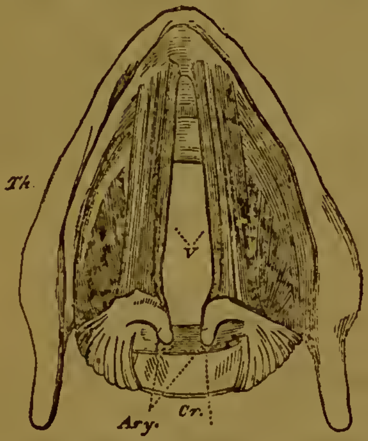

Fig. 8.—Glottis. Th, thyroid cartilage. Cr, Cricoid cartilage. V, vocal chords. Ary, arytenoid cartilage.

a V shape, lying beneath the *hyoid* bone, and above the *cricoid* cartilage. Between the thyroid and cricoid cartilages in front, a gap filled up by membrane exists, allowing motion of the former up and down. This motion is affected by the thyro-cricoid muscles on the outside of the two gristles, which pass obliquely upwards and backwards, and pull the former down. On the upper edge of the back of the cricoid are the two arytenoid cartilages, which have muscles to pull them together or asunder, and others passing to the front of the thyroid on the inside, pulling the latter cartilage up after it has been drawn down by the crico-thyroid muscle.

When the hinder edges of the vocal chords have been drawn together, so that they are parallel, voice is produced, which is modified by the lips and tongue, and becomes speech, song, cry, &c. The vowel sounds, which are continuous, could be produced without the intervention of the lips or tongue; but the consonants, which are interrupted sounds, require these in characteristic modes of action, which can be discovered by the student himself uttering the various sounds, and at the same time analysing the mode of operation.

SENSES.

234. **Sensation.**—Most of the movements of the body and its parts are in obedience to a stimulus, or irritation, direct or indirect, applied to the ends of afferent, or ingoing nerves, which transmit the stimulation by molecular change to a central nervous organ

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Sc. Ex., 1867, E.—Where is the voice produced? 233.

Sc. Ex., 1868, A.—Give an account of the manner in which the voice is produced and regulated. 233.

in the brain, spinal cord, &c. ; the latter reflect it to the motor, efferent, or outgoing nerves, the ends of which are in communication with the muscles of the part moved. This series of changes constitutes *reflex* action, the essentials of which are, therefore,

(1) An **Afferent** nerve.

(2) A **Central** organ.

(3) An **Efferent** nerve.

Examples of such are seen in the motions of the limbs when irritated below injury to the spinal cord ; in the organic functions of respiration, sucking, closure of the pupil of the eye under excessive light, &c. They are of course independent of the will and unaccompanied by consciousness.

Besides the organic sensations (188) we also have the muscular feelings, which discriminate resistance, pressure, and weight: these are very indefinitely localised.

The five senses are divided into two groups, (1) *touch*, *taste*, *smell*, having a definite localisation, but of very varied origin, and (2) *hearing* and *sight*, definitely localised, and originated by one kind of stimulus or agent only.

235. **Touch** (including heat and cold) is possessed by all the free surfaces of the body, and by the walls of the mouth and nasal passages. The internal viscera do not possess this sense, for the exposed heart has been touched when the body has been opened, without the consciousness of the owner. Where the sense is most delicate we find in the dermis multitudes of close set elevations, called *papillæ*, containing looped blood vessels and sensory nerve fibres, enlarging in some

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Sc. Ex., 1870, E.—Where is the sense of touch most delicate and how can its delicacy be roughly measured ? 234 and 235.

Sc. Ex., 1871, E.—What is a reflex action? 234. Give examples of reflex action. 192 and 249.

cases to tactile corpuscles, which are the instruments of the most delicate touch. The parts most sensitive to touch are the tongue, tips of the fingers, lips, cheeks, and palms of the hands.

The sensations of warmth and cold are due to nerves distinct from those of touch proper; and thus we have paralysis in which a limb is sensitive to change of temperature but not to touch, and *vice versa.* Like the other senses, this of temperature is relative, not absolute, cold and warm having no meaning except in reference to what has immediately preceded. Like touch, it varies in sensibility in different parts of the integument, but the parts most sensitive to touch are not so to temperature. The cheek and palms of the hand are very delicate in this discrimination.

The mode of sensation in touch is by pressure of the nerves in the papillæ; the delicacy varying with the thickness of the integument above them. If the latter be removed, and the nerves irritated, they will not register the sense of touch, but that of organic pain. The discrimination is also tested by sensitiveness to plurality of points (Weber), which is dependent on the number of the papillæ, each nerve fibre commanding over a certain district, as it were, of the free surface of the body. The most recent experiments show that the tongue can discriminate this doubleness of impression when a pair of compasses is passed over it, if the legs are separated by only $\frac{1}{30}$ inch, whereas in the back they may be three inches asunder. This discrimination is modified by the following considerations:—

(1) The sense is most delicate when the points are stretched on structures of varying character.

(2) It is rendered more delicate by moving the legs of the compasses across the parts tested.

(3) It is greater across than along a limb.

(4) Very delicate surfaces magnify the actual distances:—thus holes in the teeth are felt by the tongue as much larger than they are in reality.

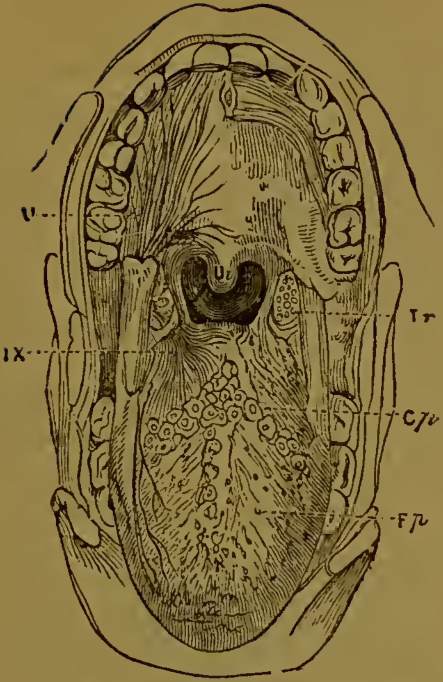

Fig. 9.—Uv, the uvula of the velum palati. Tr, tonsil. Cp, circumvallate papillæ. Fp, fungiform papillæ. IX, glossopharyngeal.

236. **Taste.**—The organ of taste is the tongue and the hinder part of the mouth; the mode of sensation is by molecular change chemically begun in the fine filaments of the nerve of the senses of taste, the *glossopharyngeal*, and perhaps part of the fifth or trigeminal nerve.

The tongue is covered over by a colloidal membrane which allows the permeation of liquids and saline solutions, but is impermeable to colloids like itself (gum, gluey, and viscous bodies generally); the latter, consequently, are tasteless. The nerves are found in the papillæ, of which there are three kinds—

(1) The **Filiform**, mostly at the tip and front part, elongated and pointed ;

(2) The **Fungiform**, over the rest of the tongue, except the back part, with broad ends and narrow bases ; and

(3) The **Circumvallate**, at the root, arranged in two files shaped like the letter V, with the apex towards the pharynx ; these are like the fungiform, but are also surrounded (circumvallated) by a wall.

These papillæ become turgid when acted upon by substances in solution capable of penetrating the mucous membrane covering their extremities. The glosso-pharyngeal nerve chiefly supplies the back part of the tongue and mouth ; the fifth nerve the front.

Tastes are of three kinds—

(1) Those in alliance with the stomach, giving sensation of relish, nausea, &c.;

(2) Tastes proper, sweet and bitter ;

(3) Tastes allied to touch, fiery, pungent, acid, sour, &c.

Some are so intimately allied to smell that when the substances producing them are masticated with closed nostrils, no impression is conveyed by the gustatory nerves—this may be tried with cinnamon.

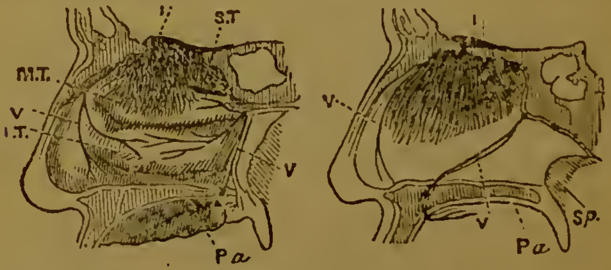

Fig. 10.—I, olfactory nerve. V, fifth nerve. Pa, palate. S T, M T, I T, superior, middle, and inferior turbinal or spongy bones.

237. **Smell.**—This resides in the delicate mucous membrane (unciliated) of the upper part of the nasal

chambers, supplied by twigs of the olfactory nerve. The olfactory is one of the two false cerebral nerves, and is continued from the olfactory lobe of the brain through the sieve-like holes of the cribriform plate of the ethmoid bone separating the bases of the anterior cerebra from the nasal chambers. It is spread out over the right and left walls of the internal nose, and of the septum between. This septum is hollowed out into three spongy or turbinal chambers, the superior, middle, and inferior, over the upper two of which the nerve of smell is spread. When the mucous membranes are destroyed or injured by severe inflammation and colds, the sense of smell is temporarily lost. Only such substances as are oxydisable can give the impression of smell as is proved by the following facts :

(1) All bodies that are odorous are oxydisable.

(2) All bodies that are inodorous are not oxydisable.

(3) No impression is conveyed to the brain unless a stream of oxygen has access to the nerves.

238. **Hearing.**—The organ of hearing is perhaps the most complicated in the whole body, and very difficult to be understood without models of a very large size.

It consists of two essential parts in man

(1) *The membranous labyrinth,* and

(2) *Scala media of the cochlea.*

Each of these is lodged in the dense petrosal temporal bone, and consists of a bag surrounded by a liquid, the *perilymph,* and containing *endolymph.* The auditory filaments are spread out on these sacs, and are agitated by the liquid contents under vibrations of the air from sonorous bodies, and by percussion from

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Sc. Ex., 1871, A.—Describe the organ of smell. How are sniffing and sneezing effected ? 237 and 216.

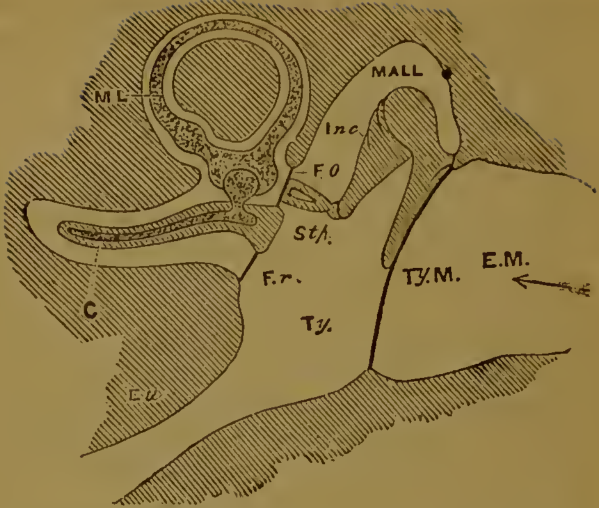

Fig. 11.—E M, auditorius meatus externus. *Ty*M, tympanic membrane. T*y*, tympanum or drum. Mall. hammer or malleus. I*nc*, anvil or incus. S*tp*, stirrup or stapes. F*o*, Fenestra ovalis. F*r*, fenestra rotunda. E*u*, Eustachian tube. M L, membranous labyrinth. C, cochlea.

minute filaments of calcareous matter, or small ear stones or otoconia (otolithes). Each of these sacs lies in a bony excavation of the skull.

The ear, as a whole, is divided into four portions:

(1) *Concha* or *auricle.*

(2) *External* ear or *auditorius meatus externus.*

(3) *Middle* ear or *tympanum.*

(4) *Internal* ear made up of the *labyrinth* and *cochlea.*

The *concha* consists of convoluted plates of cartilage which transmit the vibration of the air by conduction and reflection.

The *auditorius meatus* is a passage leading up to the middle ear, from which it is separated by a transverse membrane set at an angle of 45° called the *membrana tympani.* Behind this lies the middle ear, which consists of a chamber lined with ciliated epithelium communicating with the external atmosphere by the

Eustachian tube, and with the internal ear by two openings covered with membrane, one, the *fenestra ovalis*, leading into the vestibular portion of the labyrinth, the other, the *fenestra rotunda*, communicating with the cochlear portion.

Between the membrana tympani and the fenestra ovalis lies the chain of the ossicles, consisting of four small bones, the malleus (hammer), incus (anvil), os orbiculare (orbicular bone), and the stapes (stirrup). The malleus has a long and a short process; by the former it vibrates with the membrana tympani to which it is attached, by the latter it swings on its axis. The incus receives the impulses of the hammer bone, swings round on a short process resting on the inner wall of the tympanic cavity, and rotates a longer process which is fastened to the stapes by the intervention of the orbicular bone. The foot plate of the stirrup is attached to the membrane of the fenestra ovalis, which thus vibrates isochronously with that of the tympanum. The vibrations of the fenestra ovalis are communicated to the perilymph, thence to the endolymph, and so finally to the nervous filaments spread out on the inner walls of the membranous labyrinth and cochlea.

Two muscles restrict the vibrations of the membranes of the tympanum and fenestra ovalis, one, the *tensor tympani*, checks the former, and the other, the *stapedius*, regulates the latter.

The membranous labyrinth is that department in which quantity, volume, and probably direction are discriminated. The cochlea is employed in discriminating pitch. It is probable that the latter is furnished with nerve filaments, each of which will vibrate to one sound and to that only, so that it is like a key-board of an instrument with constant notes.

Direction is probably indicated by the labyrinth, as this is divided into three semicircular, bony, and membranous canals, two vertical and one horizontal. Of course the intensity of sound is still further increased by resonance from the bony structure of the skull which acts as the sounding board in an instrument.

The cochlea is so called because it is coiled spirally two and a half times on itself like the spiral staircase of a bell tower.

239. **Sight. Structure of the Eye.**—The eye is a complicated, globular organ, moving freely in a chamber called the orbit. In this it is kept in place by six muscles and the optic nerve, which hold it on the cushions of fat lying within the orbit, yet so as to allow of some freedom of motion. The muscles referred to are the following :—

(1) The *external rectus* rolling the eyeball outwards.
(2) The *internal rectus* acting as an antagonist to (1).
(3) The *superior rectus* rolling the eye upwards.
(4) The *inferior rectus* antagonist to (3).

These all have their origins in the back part of the orbit, where the optic nerve arises; and their insertions in broad thin plates on the outer coat of the ball. In addition are—

(5) The *superior oblique*, or *trochlear*, and
(6) The *inferior oblique.*

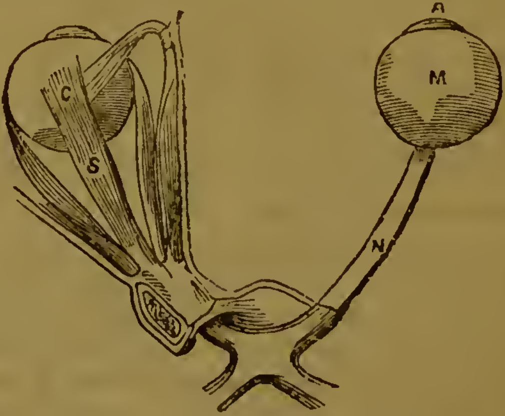

Fig. 12.—A, cornea. M, sclerotic. C S, superior rectus. N, optic nerves.

The trochlear passes from the orbit to the front, and there passing through a pulley-like loop is reflected to the outer coating of the eyeball. The optic nerve leaves the skull by a hole at the back of the orbit, entering the ball on the nasal side of the centre, and spreads out on the interior of the globe. The eye essentially consists of three tunics and three humours. The three tunics are :—

(1) The *sclerotic*, external coat.

(2) The *choroid*, middle tunic, and

(3) The *retina*, or expansion of the optic nerve. The three humours are :—

(1) The *aqueous humour* in the anterior part of the globe.

(2) The *crystalline lens* behind this, and

(3) The *vitreous humour* filling up the posterior portion of the globe.

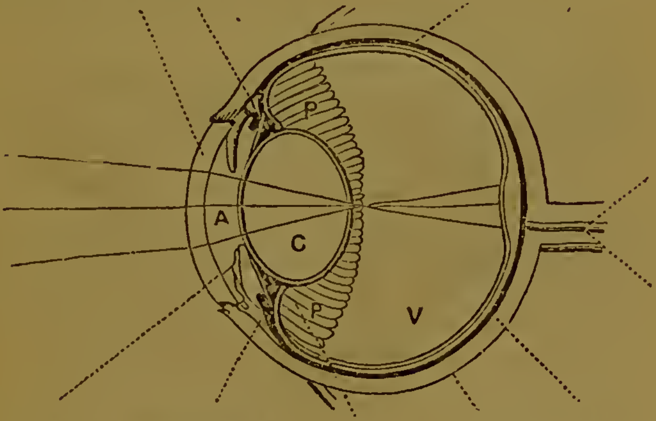

Fig. 13.—A, aqueous humour. C, crystalline lens. V, vitreous humour. P, ciliary processes.

The **sclerotic** or tough tunic is made of firm connective tissues, mostly white and opaque ; in the front, however, it becomes transparent and is called the *cornea*

This is the projection set in the ball like a watch glass in a watch, more convex than the sclerotic, and made of thin laminæ of cartilage, which can be separated by the point of a pen knife.

The **choroid** is very vascular and is lined internally with black pigment cells, like those in the skin of a frog. It covers the whole of the posterior part of the sclerotic on the inside, except where the optic nerves enters.

The **Retina** consists of an outer layer of nerve filaments, beneath which are successively met nerve corpuscles, convoluted nerve fibres, an inner and outer granular layer, and, on the choroid surface, rods and cones. These rods and cones in the pigment cells are the immediate vehicle of the sensation of sight. Its functions are to convey the vibrations of ether set in motion by the external source of light, to the rods and cones, and to transmit the change effected in or by the rods and cones to the sensorium.

240. The **Iris** is a flat, circular curtain made of unstriped circular and radiating fibres lying behind the cornea and in front of the crystalline lens, and, therefore, projecting into the aqueous humour which it divides into an anterior and posterior chamber. The centre is left open for the admission of light, and is known as the *pupil*. In man this aperture is circular; it contracts and enlarges according to the quantity of light present by the contraction of the radiating and circular fibres. The edges are firmly connected on the

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Sc. Ex., 1867, E.—What is meant by the "pupil" of the eye? 239.

Sc. Ex., 1868, E.—What is the retina, and what is its function? 239.

Sc. Ex., 1870, E.—What is the pupil of the eye? When does it become larger, and when smaller? and how is the change in its size brought about? 239.

outer circumference with the globe of the eye at the meeting of the cornea and the sclerotic, by the *ciliary ligament.*

241. The **Crystalline Lens** is double convex, more convex behind than in front, and denser than either the aqueous or vitreous humours. It is held on places by a delicate, strong, membranous framework called the *suspensory ligament*, which may be studied in the eye of an ox or a sheep. This reaches from the edges of the lens to the terminations of the choroid to the front, in what are called the *ciliary processes*, which are mere corrugations or puckerings of the anterior edge of the choroid. It is by the alteration of convexity of the anterior surface of this lens that the necessary adjustment for distance is made by the eye, when passing from an object near at hand to one more remote.

The general effect of the cornea and the three humours is to act like a convex lens in refracting the pencils of rays proceeding from every point of an object to a focus on the retina, whereby a retinal image may be portrayed which shall be transmitted to the sensorium.

242. **Blind Spot,** *macula lutea.*—The point where the optic nerve enters the eye is destitute of the rods and cones referred to (239), and is, therefore, insensible to light. This may be proved by looking at two dots on a sheet of paper. If the left eye be closed, and the left hand dot be looked at by the right eye, both it and the dot on the right will be seen at certain distances; but, if the position of the paper be altered, the left-hand dot alone will give an image, the right falling on the blind spot of the eye.

Sc. Ex., 1871, E.—What part of the retina is insensible to light? How can you prove that it is so? 242.

243. **Colour-blindness,** or **Daltonism,** arises from an imperfection in the humours by which the subject is unable to distinguish certain colours. The complementary colours are mostly mistaken as green for red, or *vice versa* ; but not always so, for in some cases green and blue cannot be at all times distinguished.

244. **Conjunctiva** is a delicate, vascular, nervous, mucous membrane lining the eyelids, and is reflected over upon the anterior sclerotic and cornea, where it becomes transparent.

245. **Lachrymal Gland.**—On the outer top corner of the eye is situated a gland that secretes a humour, which is constantly poured forth to be passed over the front of the eyeball by the lids, to wash away dust, &c. It is drained off by two minute channels, in the upper and lower lids, which unite into one at the inner angle of the eye close to the *Caruncula lachrymalis* or red spot. It is then poured through the *lachrymal duct* into the *lachrymal sac,* lying inside the nasal chamber. Under strong emotion or irritation the secretion is poured forth faster than it can be carried off, when it overflows in tears, relieving the brain of congestion.

246. The **Eyelids** are made of thin plates of cartilage, and are closed by the orbicular muscles; the upper eyelid is raised by the *levator palpebræ,* the sudden action of which gives the appearance of the eyes flashing.

247. **Duration of Impressions.**—If a lighted stick be whirled rapidly round, it will be seen as a circle of fire, proving that the impression of sight remains after

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Sc. Ex., 1869, E.—Describe the general structure of the eyeball (238), and mention the uses of its chief parts. 239, 240, 243, 244, 245.

Sc. Ex., 1868, A.—Briefly describe the structure of the eyeball, and give an account of the uses of its different parts. 239, 240, 243, 244, 245.

the withdrawal of the agent. This persistence of vision endures for about one-eighth of a second, and is employed in deluding the judgment in many ingenious toys, such as the thaumatrope, or wheel of life, the catharine's wheel, tops, &c.

NERVOUS SYSTEM.

248. **The Cerebro Spinal System,** consists of

(1) Cerebro-spinal axis, and

(2) Cerebral and spinal nerves.

The *axis* lies in the hollow of the brain case and groove of the spinal column. Each of these is lined by a tough fibrous membrane, the *dura mater*; the axis itself is closely invested by a very vascular tissue, the *pia mater*, wherein the blood vessels are interlaced, by which the medullary substance is nourished. The outer surface of the pia mater and the inner surface of the dura mater, pass into a delicate tissue, called the arachnoid, which secretes a fluid.

249. The **Spinal Cord** extends from the lower opening in the skull to the second lumbar vertebra. It is made of white and grey medullary matter, consisting of nerve corpuscles interlaced with white fibres or nerve trunks. It is cut nearly into two by the *anterior* and *posterior fissures* down the centre of the narrow neck separating which, is a small canal. Each half is divided longitudinally into the posterior, lateral, and anterior columns. From two of these spring the posterior and anterior roots of the spinal nerves, coming out at the *intervertebral foramina*, and uniting into one trunk on each side of the body. There are thus thirty-one pairs of spinal nerves from between the thirty-three vertebræ.

The anterior roots and continuing fibres are the *motor* nerves, which carry from the brain the order for action to the muscles; while the posterior fibres are afferent nerves conveying sensation of impressions made on their peripheral extremities. Both are continued up to the brain, the sensory, or afferent, crossing over first into the opposite half of the spinal column near their roots; the motor, or efferent nerves, travelling up the same half of the cord in which they are rooted until they reach the neighbourhood of the medulla oblongata, when they also cross over.

Irritation of the cut ends of the posterior roots gives sensation but no motion, while the opposite takes place when the anterior roots are stimulated.

The spinal cord is thus a communicating trunk to the brain, connecting the muscles and surfaces of the body with the seat of consciousness; but it is also a centre of nervous action itself, by means of reflex action. This power is possessed by the grey matter, the white consisting of communicating fibres only. It is in it that all those movements are originated which are performed without the will or consciousness of the subject, such as the convulsive motions performed when the soles of the feet are tickled, the secondary automatic actions, &c., and by it the general state of tonicity of the muscles and the closure of the sphincters of the body are maintained during sleep. These can be kept up even after severance of the cord, by the parts below the injury. In the lower animals flying, leaping, walking, running, &c., are

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Sc. Ex., 1868, A.—What is the structure of the spinal cord? 248. What are the roots of the spinal nerves, and how have their functions been determined? 249.

Sc. Ex., 1869, E.—What effect is produced by irritating the anterior root of a spinal nerve? 249.

Sc. Ex., 1871, E.—What is a reflex action? Give examples of reflex actions. 249, 234, and 192.

reflex actions; and as fatigue is only felt in the brain from acts proceeding from the will, we have a reason for such marvellous muscular exercises as can be performed by the lower orders.

250. The **Brain** consists of several portions lodged in the skull, and protected from injury by a casing of dense bone.

(1) The largest and most important division are the **cerebral hemispheres**, each divided into a frontal, temporal, and posterior lobe, though the division is more arbitrary than natural. The two hemispheres are connected by the *corpus callosum*, consisting of white medullary substance. The outer surfaces, upper and under, are marked out into convolutions, or *gyri*, by numerous fissures, or *sulci*. Into these the pia mater dips down with its contained blood vessels, and by their number and depth we test the intellectual rank of the owner. The exterior matter lies like a cake upon the interior white substance, as in the spinal cord. It is in the hemispheres that the functions of *will* and *intelligence* reside.

(2) **Medulla Oblongata** is that part of the brain connecting the contents of the cranium with the spinal cord. The central canal of the cord widens out in it, forming a broad cavity known as the *fourth ventricle*. Life is not destroyed by slicing away the brain from above or the cord from beneath, until the respiratory centre in the medulla oblongata be reached, when death instantly ensues. It is injury to this vital part from pressure upon it from above, or in bruising in the dislocation of the neck by hanging, &c., that causes instant death.

The medulla oblongata is the centre from which spring the nerves connected with the muscles employed in deglutition and respiration, of which functions it is specially the regulator. It is from injury to this part of the cord that death ensues, by suspension of the respiratory functions in paralysis. (216.)

(3) **Cerebella.**—Those lie at the back of the skull, and are overlapped by the posterior lobes of the cerebra. They consist of white and grey matter in laminæ; so, when they are laid open by the scalpel, they present the appearance of an *arbor vitæ*. This may be beautifully seen in the cerebellum of a sheep. The function of this part of the brain is to regulate, modify, control, and combine motions begun either spontaneously or in

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Sc. Ex., 1868, E.—What is the general structure of bone, and by what mineral substances are bones made hard? 260.

obedience to the will, so that they may be co-ordinated to specific purposes. Without this organ motion would be possible, but no harmonious movement could take place.

(4) **Pons Varolii.**—Lying immediately in front of the medulla oblongata, are layers of transverse fibres uniting the cerebella together, between which they form a kind of bridge.

(5) The **Crura Cerebri** are two broad divergent clusters of longitudinal nerve fibres from the medulla oblongata, passing to the front among the fibres of the pons varolii.

(6) The **Corpora Quadrigemina** are four hemispherical elevations of medullary matter just above the crura cerebri.

251. **Cerebral Nerves.**—The brain gives off from itself the cerebral nerves; these proceed from the cranium in pairs, issuing out through sinuses in the bone.

They are the following:—

1st. **Olfactory**, from the olfactory lobes between the bases of the anterior lobes of the cerebra and the cribriform plate of the ethmoid bone, at the top of the arch of the nose. Like the optic nerves, so called, they are not true cerebral nerves, but portions of the brain itself.

2nd. **Optic.**—These proceed from the brain in one trunk, which divides into two, each branch going to the orbit of one eye.

3rd, 4th, and 6th, are **Motores Oculi** to all the muscles of the eye, the 4th commanding the superior oblique, the 6th, the external rectus.

5th. **Trigeminal** or **Trifacial** has three branches—
(1) To the orbits and brow;
(2) To the upper lip and nose;
(3) To the tongue.

Sc. Ex., 1870, E.—Where is the medulla oblongata, and what are its most important functions? 250.

Sc. Ex., 1871, A.—Give an account of the functions of the medulla oblongata. 250.

7th. **Facial,** a motor nerve, regulating the expression of the countenance, &c.

8th. **Auditory,** leading to the cochlea and labyrinth.

9th. **Glossopharyngeal,** partly for taste, and partly a motor nerve concerned in deglutition.

10th. **Pneumogastric,** or Par Vagum. This has most extensive connections, and is traced to the heart, stomach, liver, lungs, and larynx.

11th. **Spinal Accessory** is a motor nerve.

12th. **Hypoglossal,** for the muscles of the tongue.

252. **Sympathetic** consists of a double chain of ganglia lying on the inside of the spinal column, and ramifying in the thorax and abdomen, into networks of interlaced ganglia and commissural cords upon the heart and stomach. It is connected with the cerebro-spinal axis, so that it is in many cases difficult to say how far it is implicated in the nervous functions of the body. It differs from the cerebro-spinal in the fact that there is no "white substance of Schwann" referred to (191) between the axis cylinder and the line of contour, so that a difference of colour is seen. But the functions of the two also differ, for the sympathetic are the governing power by which the circulation and other functions of the viscera are maintained, so that they minister to the organic, vegetative life as distinguished from the animal functions.

253. **Vaso Motor Nerves** are those which regulate the calibre of the blood vessels. When these are stimulated by cold they become partially paralysed, then the vessels become distended and congested, giving rise to inflammation. If the sympathetic nerves leading to the ear of a rabbit be cut, the blood vessels, being no longer under the contraction of the muscular

fibres making up their walls, become distended visibly; whereas if the cut ends be irritated, the opposite effect would take place.

254. **Brain the Seat of Mind.**—Proofs:—

(1) Mental fatigue is localised in the brain, as muscular fatigue and exhaustion are confined to the muscles.

(2) Injury to the brain is succeeded by mental incapacity or derangement.

(3) The size and development of the brain are a measure of the mental calibre.

(4) Mental work is followed by separation of the phosphates from the blood through the kidneys, and these enter largely into the composition of the brain.

(5) Animals may be kept alive for months after the brain has been extracted from the skull, but they are incapable of the least exercise of intelligence or will.

STRUCTURAL ELEMENTS.

255. **Histology** deals with the ultimate structural composition of the tissues, as distinct from the chemical. Not only has the whole organism sprung from a single cell, and become developed by the process of differentiation, but we die daily, and daily repair our losses of substance by the addition of new cell structures derived from the food elaborated in the blood. Among the simplest of these primordial elements are the cells of the epidermis or epithelium. These cells are developed in the lower parts of the dermis; they are thrust upwards by others beneath, and become flatter, drier, and more horny as they approach the surface, till they are finally thrown off from the living organism as dead, effete matter. These cells have a variety of character, and are known as—

(1) **Cylindrical Epithelium,** as in the intestines;

(2) **Globular or Spheroidal,** as in the gastric glands;

(3) **Squamous or Tesselated,** in mouth;

(4) **Ciliated,** in Eustachian tube and tympanum, bronchial tubes, lower part of nasal chamber, &c.

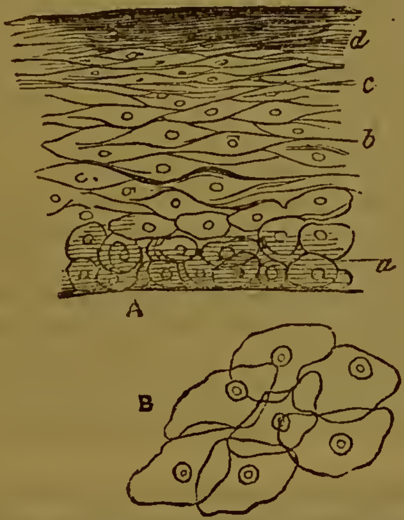

Fig. 14.—A, shows the epidermis in vertical section. *a*, *b*, *c*, *d*, are the constituent cells. B, shows the flat scales viewed from above.

256. **Nails.**—In some parts of the body the epidermic cells, instead of being cast off as they become flattened in the manner just described, coalesce into hard, horny plates, which are constantly growing from beneath and behind. As they are pushed forward in their growth from behind, they are cut when inconveniently lengthy.

257. **Hairs.**—The microscope reveals the structure of this modification of the epidermic cells, and shows it to consist of a medullary pith in the centre of the shaft, surrounded by a *cuticle*, outside of which lie the

inner and outer hair sheaths, and on the surface are the walls of the hair sac. It springs at first from a papilla at the bottom of a follicle, or sac; and is made of the horny epidermic cells, pushed up from below and continued in the shaft of the hair.

258. **Cartilage**, gristle or chondrine, is a clear, elastic, firm tissue, consisting of a matrix nerveless and bloodless, containing nuclei and fat globules. It is fed by imbibition from neighbouring porous tissues, but when once injured cannot be repaired. The ribs are connected with the sternum by cartilage: it lies between the bodies of the vertebræ, and lines, generally, the articular surfaces of joints.

259. **Fat Cells** are scattered through all the connective tissues generally, and are specially laid up in the orbits to cushion the eyes. They are spheroids of thin membrane with nuclei, and the contents may be dissolved through the thin walls. Their function is to supply material for the generation of heat and force at times when food proper is not forthcoming, and to serve more special functions, as in the case of the eyes, &c.

260. **Bone.**—This is partly earthy and partly animal matter—the former being chiefly the carbonate and phosphate of lime. The animal matter may be burnt out, leaving only the earthy in the remaining ash; or the earthy may be dissolved, leaving a framework of animal substance. The texture of bone shows the presence of lacunæ, or minute caudate cavities, which stellate into branching ramifications called *canaliculi*. The larger bones are, moreover, traversed by longer grooves connected by side branches: these are the *Haversian canals*, opening out to the outer surface of the bone, and affording access for the blood vessels. Like the other tissues, bone is being constantly used up and reconstructed, the blood vessels being the vehicles here as elsewhere of waste and repair.

261. **Teeth.**—The substance of the tooth consists of (1) *Dentine*, (2) *Cementum*, (3) *Enamel*.

The first makes up the body of the tooth, the second coats the fangs, and the third covers the crown and sides. Dentine is very calcareous, having less animal matter than true bone, and differs from it also in having no lacunæ or canaliculi. Enamel is made of hexagonal fibres set at right angles to the surface of the dentine, and arranged like the cells of the honeycomb.

In the interior of the tooth is the pulp sac, containing the dental pulp, a very vascular and nervous tissue.

PHYSIOLOGICAL CONSTANTS.

262. **Daily Losses**:—

$$\left.\begin{array}{l}\text{Lungs, 5,000 grains,}\\ \text{Kidneys, 23,000 grains,}\\ \text{Skin, 10,000 grains,}\end{array}\right\}\text{Water.}$$

Circulation.—The heart beats 75 times per minute, propelling 5 cubic inches each stroke; the blood moving in the great arteries at the rate of one foot per second, in the capillaries 1 to 1½ inches per minute.

Renal Excretion.—The kidneys pass 500 grains of urea, and 500 grains of other solid matters per day.

Red corpuscles, $\frac{1}{3200}$ inch diameter; white corpuscles, $\frac{1}{2500}$; striated muscular fibre, $\frac{1}{400}$ inch diameter; plain, $\frac{1}{4000}$; connective tissue fibre, $\frac{1}{40000}$ inch diameter.

Cones in the "yellow spot" of the retina, $\frac{1}{10000}$ inch diameter. Capillaries, $\frac{1}{3500}$ to $\frac{1}{2000}$ inch diameter.

Sc. Ex., 1868, E.—Why are teeth hard? How many sorts of teeth are there? 228 and 261.

Sc. Ex., 1870, E.—What is the number of the teeth, and of what substances are they composed? 228 and 261.

HOME EXERCISES.

263. In the following Exercises, it is intended that in the interval between each meeting of the class, which is generally a week, the student should commit to memory the first question, and write out answers to the remaining four questions in each exercise, the answers to be overlooked and corrected by the teacher, who is also recommended to examine the students orally on the subject matter of the questions. In this way the Exercises will serve for twenty weeks, and for the remainder of the time it will be found beneficial either for the teacher himself to set questions, or begin anew with the Exercises, examining the class orally each week on two of them.

EXERCISE I.

1. Learn definitions 1, 2, and 3.

2. Give an outline of the structure of the human body.

3. What are the contents of the skull, thorax, and abdomen?

4. What are the epidermis, dermis, and epithelium?

5. Describe the general arrangement of the muscles.

EXERCISE II.

6. Commit to memory definitions 4, 5, 6, and 7.

7. Name the *essential* and *incidental* chemical elements that are met with in the body.

8. Of what chemical elements are proteids, fats, and sugar composed?

9. Give proofs that the body is constantly wasting away.

10. How is the compensation for the wasting away provided for?

EXERCISE III.

11. Learn definitions 8, 9, 10, and 11.

12. For what purpose are the *aqueous* and *mineral* foods?

13. What are the *essential,* and what the *accessory* foods?

14. What purpose does *ciliary action* serve in human physiology?

15. Describe *unstriated* muscle.

EXERCISE IV.

16. Learn definitions 12, 13, 14, and 15.

17. Describe the structure of *striated* muscle.

18. What are nerve fibres?

19. What are ganglionic corpuscles, and what purposes do they serve?

20. What is rigor mortis, and how is it produced?

EXERCISE V.

21. Commit to memory definitions 16, 17, 18, and 19.

22. What do you mean by *local,* and what by *general* death?

23. Write a description of the heart.

24. Describe the systemic course of the blood. What other circulatory routes are there?

25. Give proofs that the blood circulates in the body.

EXERCISE VI.

26. Learn definitions 20, 21, 22, and 23.

27. By what means are the functions of the heart maintained?

28. What are corpuscles? and what functions do they perform?

29. What are *serum* and *crassamentum?*

30. Give the composition of the blood.

EXERCISE VII.

31. Learn definitions 24, 25, and 26.

32. Describe the uses of the blood.

33. What is lymph, and where is it found?

34. What is the difference between arterial and venous blood?

35. Describe diaphragmatic and costal respiration.

EXERCISE VIII.

36. Learn definitions 27, 28, and 29.

37. What is asphyxia, and how may it be caused?

38. What are the kidneys, and where are they placed?

39. What is the bladder?

40. Give a description of the *sweat glands*.

EXERCISE IX.

41. Commit to memory definitions 30 and 31.

42. What is bile, and what are its uses?

43. Enumerate the sources of heat in the body.

44. Where are the salivary glands? Of what use is saliva? What is its essential constituent?

45. Why is it necessary to take as food substances containing protein?

EXERCISE X.

46. Learn definitions 32 and 33.

47. What is pancreatine, and what are its uses in the system? What substance has similar uses?

48. Enumerate the absorbents, and the different substances absorbed by them.

49. Describe the mechanical processes of digestion.

50. What are the different kinds of levers? Give examples of each kind in the human body.

EXERCISE XI.

51. Learn definitions 34, 35, 36, and 37.

52. What is the difference between a *perfect* and an *imperfect* joint?

53. What are ligaments?

54. Describe the different kinds of motion performed by the limbs.

55. What are the *essentials* to the production of voice?

EXERCISE XII.

56. Commit to memory definitions 38, 39, 40, and 41.

57. Describe the organ of touch.

58. What kind of nerves are found in the *papillæ?*

59. Into what four parts is the ear divided? What are the auditory ossicles?

60. Give an account of the structure of the eye.

EXERCISE XIII.

61. Learn definitions 42, 43, 44, and 45.

62. Name the *tunics* and *humours* of the eye.

63. Describe the iris.

64. What is the cause of colour-blindness?

65. Where is the lachrymal gland situated, and what is its use?

EXERCISE XIV.

66. Learn definitions 46, 47, and 48.

67. Describe the spinal cord.

68. Of what does the brain consist?

69. What are cerebral nerves?

70. What do you mean by the sympathetic?

EXERCISE XV.

71. Learn definitions 49 and 50.

72. What are *vaso motor* nerves?

73. Give proofs that the brain is the seat of the mind.

74. What are the nails?

75. Describe the structure of hair.

EXERCISE XVI.

76. Commit to memory definitions 51, 52, 53, and 54.

77. What is cartilage?

78. What are lacunæ, canaliculi, and Haversian canals, and where are they found?

79. Of what substances do teeth consist?

80. What are *fat cells*, and where are they to be found? Of what use are they?

EXERCISE XVII.

81. Learn definitions 55, 56, and 57.

82. What is the use of the diaphragm?

83. Describe the structure of the liver.

84. What is the pons varolii?

85. How is deglutition performed?

EXERCISE XVIII.

86. Learn definitions 58 and 59.

87. Describe the organ of smell.

88. What is the crystalline lens, and what is its use?

89. Where are the coronary arteries?

90. What are *residual*, *supplemental*, *tidal*, and *complemental* air?

EXERCISE XIX.

91. Learn definitions 60, 61, and 62.

92. Describe the difference between cartilage, ligament, and tendon.

93. What is a pivot joint?

94. What is the function of the retina?

95. In what manner do the nutritious parts of food get into the blood?

EXERCISE XX.

96. Commit to memory the Physiological Constants at page 95.

97. What difference is there between the dermis and the epidermis?

98. How is the body of a man kept in an upright position?

99. What are valves? Of what use are they in veins, and in the lymphatics?

100. Describe the course of the air in ordinary respiration.

SYLLABUS OF THE SCIENCE AND ART DEPARTMENT.

SUBJECT XIV.—ANIMAL PHYSIOLOGY.

First Stage or Elementary Course.

Questions will be confined to the under-mentioned topics.

Anatomical Preliminaries.

The general build of the human body.

The meaning of the terms skull, vertebra, rib, sternum; scapula, clavicle, humerus, radius, ulna, carpus, metacarpus, phalanges (of the hand); pelvis, femur, tibia, fibula, tarsus, metatarsus, phalanges (of the foot); integument, mucous membrane, connective tissue, tendon, ligament, cartilage, muscle, nerve.

The position in the body and the general form and size of the following internal parts:—The brain and spinal cord; the pharynx, the gullet, stomach, and intestines; the salivary glands, the liver and pancreas; the posterior nares, the larynx, trachea, and lungs; the kidneys and bladder; the heart and the great vessels; the thoracic duct, and the chief lymphatic glands; the spleen; the diaphragm.

Chemical Preliminaries.

The composition of air, water, carbonic acid, and ammonia.

The chemical elements of which protein, fat, and sugar are composed.

The nature of the most important mineral compounds which are formed in the body.

The ultimate chemical products of the decay and putrefaction of the dead body.

General View of the Body in Action.

The evidence that the body constantly wastes during life; the nature of the waste products, and of the compensation for waste; the essential characters of food stuffs.

The part played by oxygen in the economy.

The number, position, and uses of the sensory organs.

The nature of cilia and the movements to which they give rise.

The physiological properties of muscular tissue. The modes in which muscles give rise to movements and sustain the body in the erect posture.

The physiological properties of nervous tissue. The general functions of the brain and of the spinal cord. Local and general death.

SPECIAL PHYSIOLOGY.

The Circulatory Organs.—The arrangement of the chambers of the heart and of its valves. The general differences between arteries, veins, and capillaries. The course of the circulation of the blood and the reasons why the blood moves only in one direction. The meaning of the beat of the heart, of the pulse in the arteries, and of the jet-like flow of blood from a cut artery. The evidence of the circulation obtainable in the living body.

The Blood.—The phenomena presented by blood drawn from the body. The general nature of the corpuscles of the blood. The general composition of the blood. The difference between blood and lymph.

Respiration and other processes which modify the condition of the Blood.—The obvious differences between arterial blood and venous blood. How venous can be converted into arterial blood out of the body. How and where venous is converted into arterial blood in the body.

How the air which leaves the lungs differs from that which enters them. The general nature of the respiratory movements. The course of the air when breathing takes place through the nose. The conditions which give rise to asphyxia.

The essential composition of the urine. The general structure of the apparatus by which its separation from the blood is effected.

The essential composition of the sweat. The general structure and functious of the skin.

The manner in which the blood enters and leaves the liver. The products yielded by the liver to the blood directly, and through the medium of the alimentary canal. The chief characters of the bile. The use of the gall-bladder.

The source of the heat of the body. The manner in which the temperature of the body is distributed and regulated.

Alimentation.—The quantity of dry solid and gaseous aliments required daily by an adult man. The classification of food stuffs. The economy of a mixed diet. What becomes of proteid, fatty, amyloid, and mineral food stuffs respectively. The nature and functions of the salivary, gastric, and pancreatic secretions. The manner in which nutritive matters are absorbed, and innutritious matters excreted, from the alimentary canal.

Animal Mechanics.—The different kinds of levers and their exemplifications in the body. The nature of joints, with examples of ball and socket, hinge and pivot-joints. The conditions of the production of the voice. The difference beween voice and speech.

The Senses and their Organs.—The general structure of the organ of touch. The means of measuring the acuteness of the sense of touch in different parts of the body.

The general structure of the organs of taste and of smell. The external auditory passage and the tympanic membrane. The tympanum and how it opens into the pharynx. The chain of ear bones and their connection on the one hand with the tympanic membrane, and on the other with the membrane of the fenestra ovalis. The form of the membranous labyrinth and of the cochlea. The nature of the endolymph and perilymph and of the otoconia. The relation of the auditory nerve to the labyrinth. The manner in which the impact of sound-waves on the tympanic membrane affects the auditory nerve.

The eyelids, and the manner in which they are moved. The lachrymal apparatus. The form of the eye ball; its general structure, and the functions of its component parts. The manner in which the movements of the eye-ball are effected. The blind spot. The duration of luminous impressions. Colour-blindness.

The Nervous System.—The difference between the cerebro-spinal and the sympathetic systems. The nature and functions of the roots of the spinal nerves. The evidence that the spinal cord is capable of effecting reflex action. The nature and functions of vaso motor nerves. The most important functional peculiarities of the medulla oblongata. The evidence that the higher faculties of the mind have their seat in the brain. The number, names, and functions of the cerebral nerves.

The subjoined is given as a specimen of the Examination Papers as a whole.

1875.

SUBJECT XIV.—ANIMAL PHYSIOLOGY.

EXAMINERS, PROFESSOR HUXLEY, LL.D., F.R.S., AND PROFESSOR M. FOSTER, M.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are permitted to answer questions from the Elementary paper, or from the Advanced paper, or from the Honours paper, but you must confine yourself to one of them.

In all cases the number of the question must be placed before the answer on the worked paper.

Three hours are allowed.

FIRST STAGE OR ELEMENTARY EXAMINATION.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions. You must *attempt* the first *four* questions on the paper; the remaining four you may select from any part of the paper.

The value attached to each question is shown in brackets after the question, but a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

1. What is the form of the valves of the veins? How do they act? By what simple experiment could you show their action in your own arm? (16.)
2. How does the air you breathe out differ from the air you breathe in? Why would you die if you were made to breathe the same air over and over again? (16.)
3. Of what chemical elements are starch and sugar composed? What becomes of them when they are taken as food? Why would a man starve if fed only on these substances? (16.)
4. When you bend your arm, so as to bring the hand to the shoulder, what is it that causes the fore arm to move? What bones enter into the formation of the elbow joint, and how are their articular surfaces shaped? (16.)
5. What is cartilage like, and in what parts of the body is it found? What are its uses? (9.)
6. What is saliva? What are its uses? (9.)
7. Where is the mitral valve placed? What is its structure and use? (9.)
8. Explain how the contraction of the diaphragm causes inspiration. If holes were made in the walls of the chest so as to open into the cavities of the pleuræ, what would be the effect of the movements of the diaphragm? (9.)
9. In what respects are the hip-joint and the shoulder-joint like one another, and in what respects do they differ? (9.)
10. What vessels supply the liver with blood? What vessels carry away its blood? Where is the bile formed, and how does it reach the duodenum? (9.)
11. Why is a man whose back is broken unable to move his legs, though they may be moved violently when the soles of the feet are tickled? (9.)
12. What is meant by "long-sight" and "near-sight"? How may each be remedied? (9.)

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